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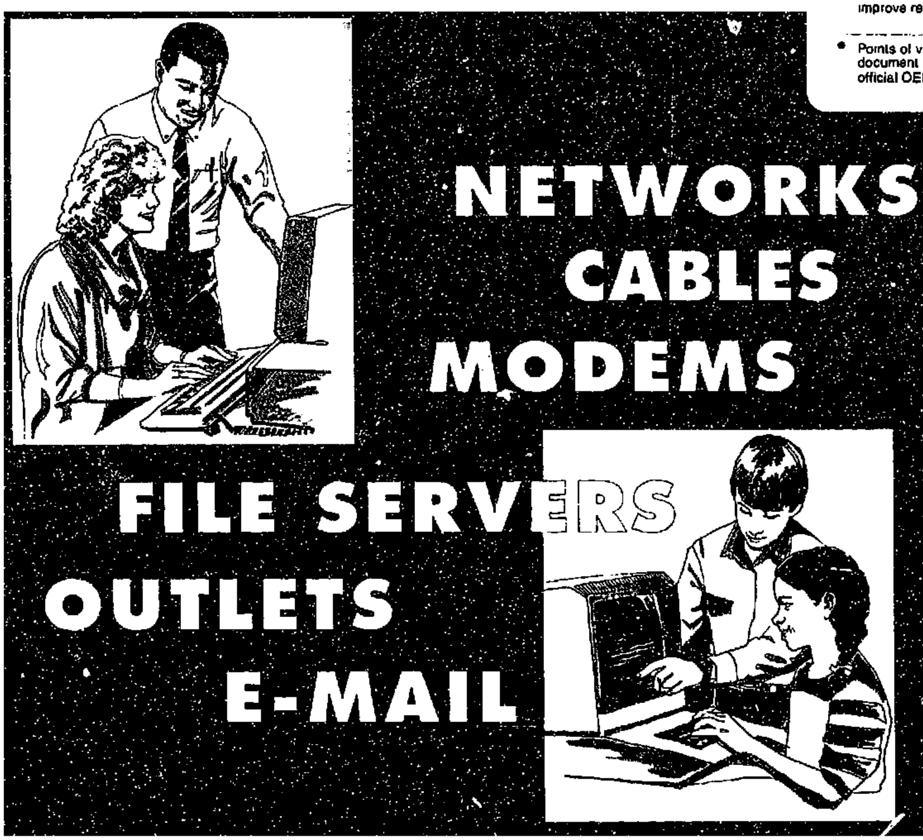
ABSTRACT

This guide provides the layperson with a concise overview of factors to consider when making plans to outfit elementary and secondary schools with technology inexpensively. The guide draws on the knowledge of consultants, architects, electronics engineers, and the experiences of educators who have been involved in the process of designing schools that allow for efficient and cost-effective use of new technologies. The guide includes sections on: the importance of planning; the basics of networks; the cost of technology; implications for school design; what technical information the planners need to know; and resources for advice on planning for educational technology, including contact names, addresses, and telephone numbers. The guide contains 12 appendices on the following topics: the planning process for integrating technology into the PK-12 curriculum; the potential of technology; components of the instructional technology framework; a list of technology design consultants suggested by Wisconsin school district personnel, with a chart showing which services each firm provides; questions to guide the architect selection process; types of wires and cables; diagrams of local area network topology; costs of technology; a list of items in a technologically current classroom; distance learning classroom floor plans; schools already designed for new technology; and an annotated bibliography of 17 sources with availability information provided. (SWC)


NETWORKS
CABLES
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Designing Schools to Accommodate Technology

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Foreword

New technologies present w possibilities for educating our children. New possibilities also create new challenges. Educators and community members may find themselves intimidated by the prospect of keeping their schools current with rapid technological changes. The key to staying up-to-date and preparing children for the future is planning. This guide provides the layperson with a concise overview of what to consider when making plans to accommodate technology in schools. The guide draws on experiences of educators who have been involved in the process of designing schools that allow for efficient and cost-effective use of new technologies. I am pleased to make this publication available because it challenges us to take advantage of what technology has to offer our children.

John T. Benson
State Superintendent of Public Instruction

Acknowledgments

This publication grew from the content of a series of handouts used in presentations on technology and school design. It draws on the knowledge of Wisconsin Department of Public Instruction (DPI) consultants as well as architects and electronics engineers and on tne experience of educators who have created schools that allow efficient and cost-effective use of the new technologies.

Staff of the DPI's Division for Libraries and Community Learning played major roles in developing this publication. William J. Wilson is the Assistant Superintendent for Libraries and Community Learning. Gordon Hanson, consultant for Instructional Telecommunications; and Neah Lohr, consultant for Microcomputers and Instructional Technology, helped to develop the material and reviewed it for accuracy and completeness. Brenda Soldner, program assistant, helped with document preparation and data verification. Members of the division's Publications and Media Services Team, who provided printing, editorial, and typographic services, include Gail Endres, print manager; Dianne Penman, typesetter; and Brian Satrom, text editor. Brad Adams, DPI facilities consultant; Will Ashmore, National Diffusion Network facilitator; and Carolyn Winters Folke, DPI Chief Information Officer, also reviewed and commented on the material.

Persons outside the department also provided valuable advice and assistance. Jon Jenson and James Kirchstein, who were on the staff of the University of Wisconsin System architectural and engineering staff, helped develop appendix E, Questions to Guide the Architect Selection Process, along with Carol Williamson, QBS facilitator for AIA Wisconsin. James Romlein, president of MIS Labs, Inc., a telecommunications engineers consulting firm in Watertown, Wisconsin, provided technical guidance for the appendix on wiring.

Persons and organizations that contributed drawings of distance-learning facilities for appendix J include Peter Nordgren, director of the Media Resource Center at the University of Wisconsin–Superior, as well as the Plymouth and West Bend school districts.

Thanks to *T.H.E. Journal* for permission to reprint the article on the cost of technology in appendix H, to the North Carolina Department of Public Instruction for the drawings of network topologies in appendix G, and to the school districts that provided information about their programs for appendix K.

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Introduction

Communities and school boards across the state seem to be struggling with a persistent technology-related question: Can buildings or additions be designed so the inevitable changes in equipment, wiring, and information-handling methods can be accommodated without great expense? This publication provides basic information and guidance needed to answer this question. To do so, it draws on the knowledge of architects and electronics engineers and on the experience of educators who have created schools that allow efficient and cost-effective use of the new technologies. The scope of this publication includes computers with related equipment and software, networks and cabling, communications systems (including those used for distance learning) that carry data as well as voice and video signals, and clock and bell systems.

The guide gives the most essential information in a concise outline form, provides appendixes that fill in necessary details, and points the way to more comprehensive resources in the bibliography. Publications related to technology will always need to be revised. The outline/appendix format should allow the reader to update the contents with revisions and related material. Ideally, some additions will come from readers who will share their school district's experiences and thereby help others identify potential problems.

Questions or comments about this publication or information to be shared with future readers can be sent to Richard Sorensen at the Department of Public Instruction, Bureau for Instructional Media and Technology, P.O. Box 7841, Madison WI 53707-7841, or call (608) 266-1924. For e-mail contact, use sorenrj@mail.state.wi.us.

The Importance of Planning 1

People involved in building or remodeling, especially where new technology is involved, say that planning is the single most important element in assuring success. The following components of effective planning have been distilled from the comments of those who have been through the process.

Involve All Significant Persons

The first step is to create a planning team representing the likely users and managers of technology in the schools as well as the various stakeholders in the educational enterprise. The planning team may be called a facilities and technology team or some other appropriate name, but this document will use the term *planning team*. Teachers (including special education teachers, the library media specialist, and other specialists) should be represented along with administrators, program coordinators (such as the district library media coordinator and computer/technology coordinator), support staff, custodians, school board members, parents, business and civic leaders, other members of the community, and students. The planning process will be aided if the team has access to an electrician, an architect, an engineer, and representatives of technology equipment and software vendors. The team needs to be mindful of potential conflicts of interest, since some of these persons could be suppliers of paid services or products for the school district.

Define the Scope of the Task

The planning team must have a clear understanding of

- the overall educational mission of the school district.
- how various technologies will play a part in students' lives, work, and learning in the future.
- the limits of the planning committee's responsibility. For example, does the committee's work end with a list of overall goals, or should it extend to making specific recommendations for building materials and space allocation?
- the specific end product expected, for example, a written plan, a building design, or detailed educational specifications.

Provide a Base of Knowledge for Planning Team Members

Technologies are many, varied, complex, and ever changing. All members of the team should understand at least the basic components of educational technology: equipment, networks, and the new media. Section 2 focuses on networks, and section 3 looks at the cost of technology. Section 4 describes the implications of technology for planning buildings, and section 5 lists the kinds of information that can be obtained from experts. Section 6 identifies some agencies and persons who can provide additional help. Most of all, the planners should understand how the various technologies improve teaching and learning and should be familiar with the district's overall plan for using technology.

Appendix A, Planning Process for Integrating Technology into the PK-12 Curriculum, illustrates the steps in the overall planning process. Appendix B, The Potential of Technology, provides some examples of how technology can improve teaching and learning.

Besides reading these sections, individual members should accept responsibility to

- share with other team members information they obtain about how technology affects teaching and learning;
- visit schools designed to accommodate technology;
- attend instructional technology conferences or workshops;
- attend demonstrations of new equipment, systems, or materials;
- observe the use of technology being integrated into the curriculum; and
- become users of technology in their own work and avocations.

Determine What Functions Should Be Handled by Technology

While not every function should be automated, proper use of technology can bring improvements to many areas, such as teaching and learning activities, grade reporting, attendance, pupil data, fees, scheduling, clocks, bells, and communicating with staff and parents. The West Allis–West Milwaukee school district used a tree diagram to help the planning team members identify where the district had already applied technology and where the district could use it in the future to improve efficiency. At the root area of the tree were listed the district's early applications of computers; present applications filled the trunk area; and among its branches, the members of the planning team wrote in their suggestions for future uses of electronic technology. Filling in the historic and current uses provided a jump start for the process.

Identify Components Already in Place

Often, a school district can use existing equipment in new ways to avoid the high cost of replacement. It is useful to make an inventory of existing equipment, listing the type, location, and how it is being used. It is usually not necessary for this purpose to know serial numbers, age, vendor, and condition of equipment. Some examples of how equipment can be used for new purposes are found in appendix C, Components of the Instructional Technology Framework.

Consider Hiring a Professional Technology Design Consultant

A number of school districts have received valuable advice from consulting firms knowledgeable about the hardware and software needed to make a wide variety of technologies available to teachers and students. Appendix D, Technology Design Consultants, lists firms identified by Wisconsin school districts as having this knowledge. Inclusion on this list does not imply endorsement or recommendation, and the list is subject to continuous updating. It does provide a start, however, for districts looking for consultant help. Reputable firms will often provide a list of school districts that have employed them in the past.

Use Technology Wherever Feasible to Facilitate the Planning Process

Word processing and electronic mail bring speed and accuracy to correspondence and communication. An electronic database is useful for listing any collection of data in a way that each segment can be analyzed for relationships and duplication. Many planning groups list objectives in a database along with the resources needed to implement them, and then break out the resources needed by dates, by source, by person responsible, and so forth. Curriculum goals can be listed in the same way with associated objectives, courses, departments, personnel, media, technology, and other implementation factors easily grouped and analyzed.

Screen Architectural and Engineering Firms to Determine Their Experience with Educational Technology

When it comes to developing the actual plans for a new building or a major remodeling project, a competent architectural and engineering firm is of utmost importance. Not all firms are qualified to recommend appropriate networks and information technology systems for schools. Appendix E, Questions to Guide the Architect Selection Process, will be helpful in determining whether a particular firm can provide the assistance required. These questions were developed in cooperation with the Wisconsin chapter of the American Institute of Architects, AIA Wisconsin, and have been incorporated into that association's Qualifications Based Selection (QBS) process. One of the questions the QBS process asks is, What experience does your firm and/or consultants have in designing comprehensive technological systems that support teaching, learning, administration, and communication in elementary and secondary schools? The questions i.. appendix E build on this foundation. For more information about QBS, a free service of AIA Wisconsin to help public agencies select the right design firm for its project, call (608) 257-8477.

Evaluate the Teaching and Learning Improvements

No group is better able to assess whether the new or remodeled school is accomplishing what was intended than the original planning team. Once the school is occupied and teaching and learning is underway, as many members as possible of the original planning team should gather to assess whether the educational benefits of the technology planning process are being realized. This effort should identify problems and lead to solutions.

The Basics of Networks 2

While not everyone on the planning team needs to know all the details of how to connect computers, printers, file servers, modems, television distribution systems, clocks, bells, and telephones throughout a school or district, there are some basic things all planners need to know. As with the potential of technology for teaching and learning, if one does not know what networks can do, one cannot make intelligent decisions about how they should be used. Planners should know the following.

Purposes of a Network

Networks connect. They connect people to pieces of equipment and software but, most of all, to ideas, information, and each other. They help teachers and students bridge small or great distances to bring data, text, pictures, sound, and even the real time presence of another person to the desktop or the classroom projection screen.

Sharing Hardware and Software

Printers, CD-ROM drives, mass storage disk and tape drives, modems, and other computer-related hardware can be shared by many workstations with a network. In addition, the library catalog, electronic encyclopedias and reference materials, and all or portions of the Internet's vast store of information can be accessed from every classroom, workroom, office, and even homes. Student data can be made available as desired. Site licenses can be purchased to make software or courseware accessible without loading it on individual workstations.

Accommodating Diverse Teaching and Learning Styles

Many software packages are designed to enable group projects and foster cooperative learning. The interconnectedness of networked software creates an environment that fosters development of communication skills and the ability to work together. Computers are eternally patient, give immediate feedback, and involve students personally in the learning process.

Access to a Wide Range of Television Resources

If a school district has access to television programming via a local cable company, a satellite receiving dish, or a distance learning consortium, a well-designed network can make that programming accessible throughout the building. Each classroom can literally bring in resources from anywhere in the world.

High Speed Transfer of Data and Normal Communication

Electronic mail and data transfer saves time and prevents errors by eliminating rekeying of correspondence and documents. E-mail messages are usually delivered more reliably, read earlier, and answered more promptly than those written on paper.

After-hours Access

Networks allow students, teachers, and members of the community to gain access to the library's online catalog and its electronic resources, to a homework hotline, to course information for home-bound and home-schooled students, to e-mail and discussion groups, and perhaps even to the Internet. These resources can be available evenings and weekends as well as during the school day.

Network Contents

While the technical contents of a network would require a degree in electronic engineering to understand (or even pronounce), basically, they boil down to hardware, cables, software, physical space, and an essential (but often overlooked) human component known as a system operator.

Hardware

Computers are a major network component, along with peripheral equipment such as file servers (large-capacity, high-speed computers that store shared software and manage the activities of the network), workstations (computers and attachments on someone's desk), printer selectors, data storage devices, CD-ROM drives, interface cards, controllers, multiplexers, routers, bridges, an uninterruptible power supply, transceivers, modulators, transmitters, receivers, surge protectors, amplifiers, repeaters, modems, and equipment racks.

A network can also include television equipment, such as monitors, cameras (still and motion), videocassette recorders (VCRs), amplifiers, computer interfaces, projectors, and videodisc players. A network can also include telephone and intercom equipment, such as a central exchange, punchdown blocks, equipment racks, patch panels, microphones, and speakers. Bell and clock controls may also be included, such as master clock, security, and fire alarm controls.

Wiring and Cables

While wireless communication is used in some applications and may become more common in the overall design of networks sometime in the future, cables of some type are needed to connect the various components to the user workstations.

Fiber optic cable is the fastest and has the greatest capacity (bandwidth) and interference protection of all types of cable but it is expensive, has special installation requirements, and needs signal translators at each end. Copper wire comes in several grades or levels and is the converse of fiber in terms of cost, speed, capacity, connectivity, and interference protection. Coaxial cable is somewhere in between in most of these areas. Choosing the types of cable for various parts of the network is an area where the advice of an electronics engineer (preferably one who is independent of network system vendors) is most helpful. Additional information about the types and capacities of network cabling is found in appendix F, Wires and Cables. Network cabling is also discussed on pages 439-41 of Richard W. Boss's "Facilities Planning for Technology," in *Library Technology Reports*, vol. 31, no. 4, July-August 1995. A list of independent electronics engineering firms is found in appendix D, Technology Design Consultants.

Space

The cables, along with the file servers, routers, amplifiers, and so forth that they connect, need space to exist and to be serviced. Telecommunications and equipment closets are not a luxury but a necessity in any building that has a network or plans to have one in the future.

Software

Network *management* software directs the traffic of the network by making and breaking the desired connections among the various components in response to user commands or preprogrammed instructions. *Communication* software sends and receives e-mail, fax, and Internet transactions. These two types of software are essential to the network itself, but other types of software can be made accessible to all users through the network. For example, *instructional* software includes a variety of teaching and learning programs from tutorials to simulation programs. *Classroom management* software helps teachers create student lists and seating charts, calculate and record grades, and graph the progress of individual students and groups. *Graphics or production* programs enable teachers and students to create publications or presentations. *Assistive* software, such as voice recognition and voice generation software, enables students with exceptional learning needs to read, hear, operate computers, and communicate. *Administration* software helps school or district offices maintain student and staff records and manage correspondence, record keeping, financial accounting, and communication.

Staff

Every district should have a *network system operator* (sometimes abbreviated "sysop") who understands all aspects of local and wide area networks. This person, typically a technician, would install new hardware and software, maintain the network, and solve problems as they arise. An *instructional technology coordinator* is the other essential position. This person would manage the district's investment in technology of all kinds, coordinate its use in all areas of the curriculum and administration, and provide professional development for faculty and staff. Teaching experience is important for this position because of the emphasis on curricular applications, modeling the use of technology in the classroom, and professional development. The district might also employ or contract for *computer repair technicians* for routine maintenance and repair of computers and related equipment.

Scope of a Network

Scope refers to its reach. Usually a local area network (LAN) connects users within a single building or within workgroups within the building, and a wide area network (WAN) connects users in one building with users in other buildings, cities, districts, states, and so forth. More precisely, Richard Boss states, "A Wide Area Network (WAN) is created whenever LANs are connected to one another through the facilities of a telco, a private data communication carrier, or other common carrier" (Boss, 1995). Typically, a school district would construct a WAN that connects the building LANs to one another and to other LANs within the community and CESA. Connection to the Internet would enable further connections.

Topology (Connecting the Parts)

Various designs have proven most efficient for certain applications or for certain hardware and software configurations. An electronics engineer specializing in network design would be able to analyze the capacities and connections needed and recommend a star, ring, tree, or bus (line) design, or some combination of these as appropriate. Appendix G, LAN Topology, provides diagrams showing the various configurations.

More Information

Ann Barron and Gary Orwig's *New Technologies for Education: A Beginner's Guide*, Eddie Kee's *Networking Illustrated: The Full Color Guide to How it all Works*, and Richard Boss's article "Facilities Planning for Technology" in *Library Technology Reports* provide more information about the structure and purposes of networks. These resources and others are listed in the general bibliography, appendix L.

Reference

Boss, Richard W. "Facilities Planning for Technology." *Library Technology Reports* 31.4 (July-Aug. 1995), p. 449.

The Cost of Technology 3

A major benefit of the intense research and development activity in electronics industries has been the steady decline in the cost of equipment, along with the increase in storage capacity, speed of processing, and quality of audio and video transmission. At the same time, software and instructional materials developers continue to find new ways to improve learning with more effective media. Most school districts will move to more effective technology as financial resources allow.

While it is impossible to give reliable cost estimates for the many components of instructional technology, some general estimates for typical components might be helpful. For example, the wiring, cabling, transmission equipment, and physical space to install a local area network (LAN) in an existing elementary school would cost between $30,000 and $50,000 (1995 estimates). This would enable the transmission of voice, data, and video signals throughout the school building. *Not included* in this estimate are individual computer workstations, television receivers, file servers, and necessary remodeling. The network would connect classrooms and offices to each other and to whatever resources are available, such as television programming, data, the Internet, the library media center's online catalog, and other electronic reference tools.

For a detail d analysis of the cost of computers and other components, see appendix H, Costs Associated with Technology.

Experienced planners suggest that one always build in *capacity* for updating. For example, additional wiring, or the ducts or conduits to carry it, can be installed while a building is under construction at a much lower cost than would be the case after the building is finished.

Implications for School Design 4

What have those who helped design a school to accommodate technology (or those who worked in the resulting school) learned that would help others just starting out on such a project? Here is what they suggest.

Install conduit or troughs for wires and cables above the ceiling or in the floor. Though they will still add to the total cost, including them in the original design and installing them at the time of initial construction is much less costly than breaking into existing walls and ceilings later.

Provide space for telecommunications or equipment closets. Wires connect file servers, routers, amplifiers, and so forth to the end-user equipment, which could be in virtually every room of the school building. The file servers, routers, and amplifiers require space, electrical power, and climate control. Over the years, many of these connections will need to be changed because of new equipment, new user stations, new software, and other reasons. Therefore, the closets built for this purpose need to be large enough to accommodate not only the equipment but the people who make and remake the connections. Experienced planners suggest at least one telecommunications closet with a minimum of 25 square feet of space for a building under 5000 total square feet. Telecommunications closets must have proper ventilation, air filtration, heating, cooling, humidifying, and electrical power as well as plywood wall panels to permit mounting equipment racks. In multistory buildings, the telecommunications closets should be located directly above one another to eliminate unnecessary horizontal wiring.

Plan plenty of electrical outlets (or junction boxes) and circuits. Electrical power service in each classroom should include at least one quadplex outlet in the center of the typical teaching wall, at least one duplex outlet on each wall with outlets no more than ten feet apart, and at least four 15-amp circuits providing electrical power. The power should be "clean," allowing no spikes or drops, and causing no interference to electronic devices. Some additional features are listed in appendix I, The Technologically Current Classroom.

Diffuse the natural light from skylights and windows. While natural light is beneficial in many ways, it is subject to swings in intensity and direction and will cause reflections on computer screens and projection surfaces. Shades or louvers might be needed to eliminate this. Some schools have installed screens or baffles to diffuse the light from skylights. Richard W. Boss says, "Ideally, all lighting throughout the facility should be indirect, recessed, or parabolic so that glare on screens—whether computer, video, or microform—will not be a problem" (Boss, 1995).

Make sure the bank of ceiling lights parallel to the projection screen wall can be switched off without turning off the rest of the room lights. Room lights can wash out dim projection images such as those from computer projection panels used with overhead projectors. Theaters and professional presentation rooms sometimes use recessed incandescent lights controlled by rheostats to achieve proper light control.

Provide an environment free of static electricity and dust. Humidification, appropriate floor covering, and alternatives to the chalkboard are essential wherever computers will be used. Richard Boss says, "Hard surfaced, nonconductive flooring or special antistatic carpet woven with conductive fibers should be used in computer and communications rooms, with the minimum antistatic rating less than 1,000 megohms . . . . If a piece of equipment cannot be grounded, antistatic chair mats that can be grounded should be used in front of the equipment" (Boss, 1995).

Make sure all spaces are as adaptable as possible to changing needs. An open concept design offers optimum flexibility but does not separate noisy from quiet activities and requires floor or ceiling cabling to provide electrical and data access. Movable dividers and demountable walls offer some ways to separate activities but do not solve the power and data access problems.

Be sure the library media center and communications hub are centrally placed. Careful discussion of what resources need to be accessed by the most users will bring to light those functions or areas that should be most centrally located.

"Older and wiser" planners have also provided a helpful list of mistakes to avoid.

- Do not forget to plan for future wiring and cabling needs as the building is being designed.
- Do not skimp on the number and size of wiring closets.
- Do not try to get by without sufficient technical staff, such as a network administrator or system operator.
- Do not assume that "if we buy it, they will use it effectively." Teachers need to be involved in identifying the needs for technology and assessing potential solutions. In addition, time needs to be budgeted for familiarization and training and for exploring what technology can do for teaching and learning. Insufficient time for staff development is the most commonly cited reason for poor use of technology.
- Do not exclude the library media program from the planning process. Surprising as it may seem, the school's major source of information is sometimes overlooked. Whether or not the library media program is a leading force in adapting technology to education, so much will be lost by omitting it and so much will be gained from including it, that library media staff need to be involved in the planning from the beginning.
- Do not forget to provide surge protectors and an uninterruptible power supply (UPS).
- Do not forget to maintain a detailed map of the network. Even if the person who figured out how to connect all the parts of the system never has a sick day or retires, human memory is subject to occasional lapses, and tracing the cause of a classroom software problem will be much less frustrating and costly if a carefully drawn and annotated map shows where each wire begins and ends. The North Carolina guide for cabling design says:

> The use and reassignment of wires and cables in a universal cabling system must be supported by good documentation. Even the smallest of these systems will consist of literally hundreds of discrete wire segments, outlets, patch panels, and other components that can be arranged in endless ways. Knowing at any time exactly how the system is presently configured is critical. A sound cable management system is essential in doing so. A well constructed cable management system will support the following important functions: troubleshooting, preventive maintenance, system implementations and asset management. When problems occur that suggest that the wiring media is the culprit, documentation regarding the entire circuit involved is fundamental to the analysis that follows. A well-designed cable management system will enable the technician to trace specific circuits end-to-end, including all intermediate terminations, cross-connections, and the specific paths involved. Moreover, the same documentation will identify alternative circuits that can be used to bypass the troubled area. This application has obvious implications in the context of disaster recovery plans. (North Carolina Department of Public Instruction, 1992)

• Do not buy a "turn-key" system without research. Buying an information network is like buying a stereo component system, except that it is more expensive. The time and effort spent identifying needs, checking with experts, and deciding on the right pieces pays off well and provides a good foundation for future improvements. It may be that a completely assembled package is just what the school district needs, but the needs analysis and evaluation should point to this, not just convenience.

References

Boss, Richard W. "Facilities Planning for Technology." *Library Technology Reports* 31.4 (July-Aug. 1995), p. 434.

North Carolina Department of Public Instruction. *A Primer for Cabling Design and Implementation: Considerations for Decision Makers*. Raleigh: the Department, 1992, p. 10.

What Does One Need to Know? 5

The planning team's job is to determine needs based on the school's educational mission and curricular goals, analyze improvements technology can make possible, and make decisions on how best to accommodate that technology in the design of buildings.

Sometimes this decision-making process demands technical knowledge that no one on the planning team has or would be expected to have. This is where consultants are helpful, such as those listed in appendix D, or technical books, such as those listed in the bibliography (appendix L). Often, members of the planning team can take on responsibility to obtain the needed information and become the resident experts or contact persons.

Some of the categories of information needed include the following:

Specifics about capacity and speed of computers and peripheral devices and which computers are best for certain applications. Some of the items in the bibliography provide basic information, and equipment vendors can supply current data. If the planning team can communicate clearly how they see technology helping to accomplish educational objectives, technology consultants can provide the technical details needed to make the right decisions about equipment.

The type of wiring that is best for specific applications. Appendix F identifies the types of cabling used in network installations. As with equipment, technology consultants are usually better prepared to match network topology and cable capacity to the educational specifications developed by the planning team.

The distance learning technology and designs most effective for the district's needs. *Instructional Telecommunications: A Resource and Planning Guide*, written by Gordon Hanson of the Wisconsin Department of Public Instruction, provides extensive information about traditional and emerging communications media, including satellites, microwave television, and fiber optic transmission systems. The bibliography (appendix L) provides ordering information for this publication. Appendix J, Examples of Distance Learning Classroom Designs, contains some examples of room designs that have proven useful in school and university settings.

Where Does One Go for Help? 6

School districts have many options for assistance in planning for educational technology. The use of technology design consultants is suggested in section 1, and appendix D lists some firms suggested by Wisconsin school districts.

It is also helpful to contact schools or school districts known to have accommodated technology effectively in their educational program. A list of those known by DPI consultants to have done this is found in appendix K, Schools Designed to Accommodate New Technology.

The Wisconsin chapter of the American Institute of Architects, AIA Wisconsin, offers a Qualifications Based Selection (QBS) process to identify architectural firms with appropriate qualifications. The service is free, and school districts are advised to take advantage of this service when planning for any remodeling or new construction. For information call (608) 257-8477.

The International Society for Technology in Education (ISTE) is an organization of persons responsible for and interested in instructional computing. It produces and distributes publications related to instructional technology and provides conferences and other services. ISTE administrative offices are located at 1787 Agate Street, Eugene, OR 97403-1923, telephone (541) 346-4414, fax (541) 346-5890.

The Wisconsin Society for Technology in Education (WISTE) is the state affiliate of ISTE. Robert Patton, computer/technology coordinator for the Mequon–Thiensville School District [(414) 424-2400] is the 1995-96 president. WISTE publishes a newsletter several times each year, sponsors an annual conference, and cooperates with other associations to present workshops and conferences.

The Wisconsin Educational Media Association (WEMA) promotes the development and effective use of all forms of instructional media and technology. The administrative office is located at CESA 3, P.O. Box 5A, Fennimore, WI 53809-9702, telephone (608) 822-3276. WEMA holds an annual spring conference and fall workshops.

The Wisconsin Library Association (WLA) and its school division, the Wisconsin Association of School Librarians (WASL), promote excellence in library and information services to students through school library media programs. The WLA administrative office is located at 4785 Hayes Road, Madison, WI 53704-7364, telephone (608) 242-2040.

Finally, DPI consultants have current information and resources related to using technology effectively in teaching and learning. These resources include sample school district technology plans and requests for proposals. They also are familiar with school districts that have planned well for its use. The following can offer assistance.

- Brad Adams, School Facilities, (608) 266-2803.
- Gordon Hanson, Instructional Telecommunications, (608) 266-7112.
- Neah Lohr, Microcomputers and Instructional Technology, (608) 266-3856.
- Richard Sorensen, School Library Media, (608) 266-1924.

Appendixes 7

A. *Planning Process for Integrating Technology into the PK-12 Curriculum*
B. *The Potential of Technology*
C. *Components of the Instructional Technology Framework: Using What Is Already in Place*
D. *Technology Design Consultants*
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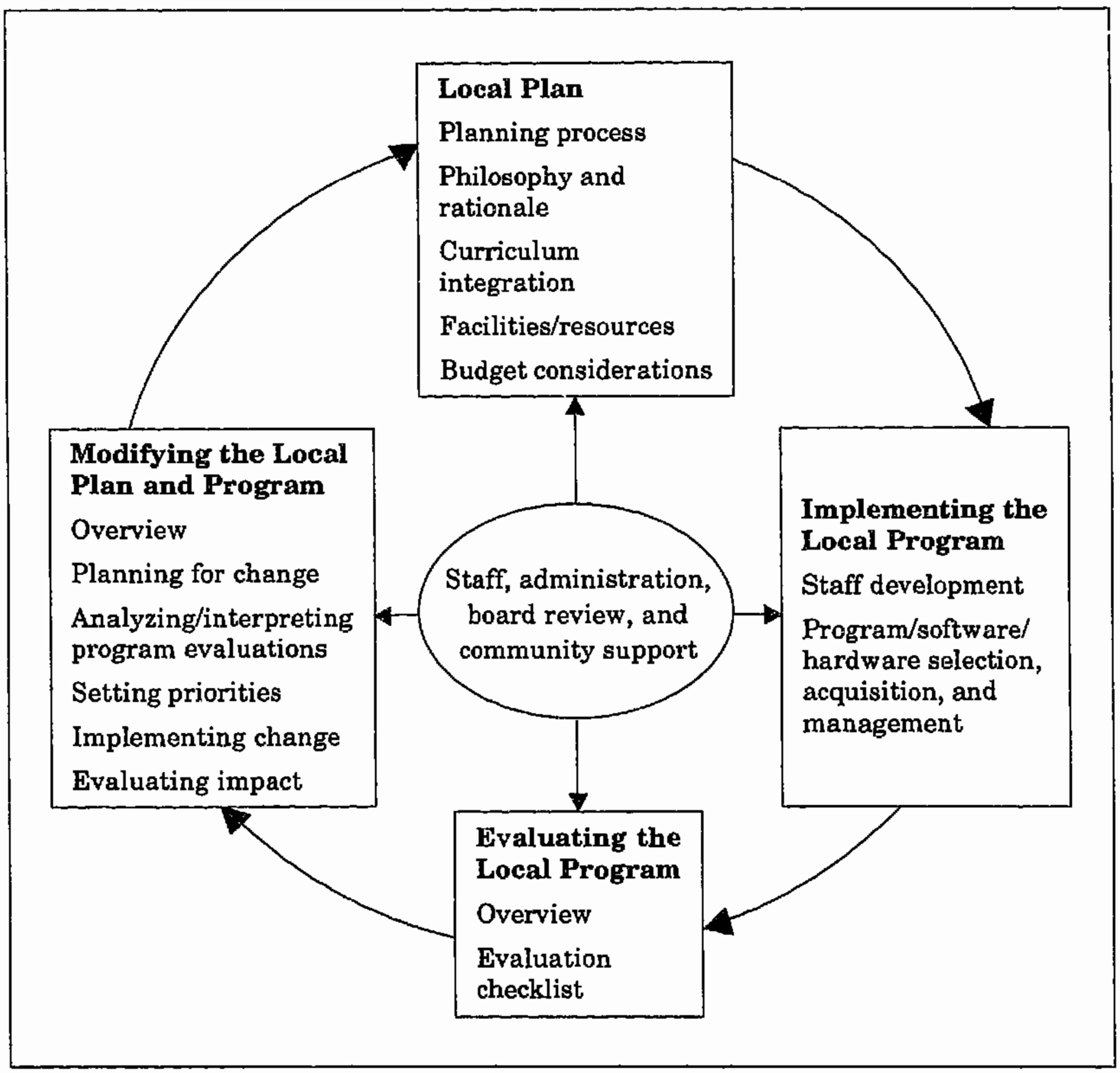
Planning Process for Integrating Technology into the PK-12 Curriculum

The school district needs to bring appropriate parties together to analyze how technology can help accomplish the district's educational goals and define practical steps for acquiring components in a systematic and equitable manner. The diagram below illustrates the steps in the planning process. Note that "facilities" is one part of the plan, and evaluation of results and modification are major steps in the process.



Adapted from *A Guide to Curriculum Planning in Computer Education*, DPI, 1987, bulletin no. 7470.

The Potential of Technology

Good design is based on purpose and functionality. If one wishes to design for technology, all the members of the planning team need to have a common understanding and agreement on how the new technologies support and improve teaching and learning. The following information may help to build that understanding.

Over the years, teachers and administrators learned to adapt basic computer applications, such as word processing and database management, to educational functions. Eventually, teachers and software companies developed specialized softwaie to manage many of the tasks associated with teaching, learning, and operating schools.

Early computer programs imitated traditional instructional materials. Drill and practice programs were like electronic flash cards. But today's programs go beyond simple recall of facts or processes and capture the learner's interest with color, multisensory appeal, and game-like interaction.

Teaching and Learning

Word processing programs reduce the drudgery of rewriting without losing respect for appropriate grammar, correct spelling, and good style. Tutorial programs take students step-by-step through a complex process with opportunities for repeating segments or skipping over what they already know. Simulation games place students in the midst of a realistic experience, calling on them to apply what they have learned and motivating them to learn what is needed to solve real-life problems. Computers can give immediate feedback and involve students personally in the learning process.

Classroom Management

Database management programs enable teachers to create student lists and seating charts, calculate and record grades, and graph the progress of individual students, groups, and the entire class. Using a word processor, a digitizing program, and video recording equipment, a teacher can develop an electronic portfolio where student achievement and performance records can be maintained. Writing samples, presentations, and performances can be integrated into the record.

Graphics and Production

Publishing or authoring programs enable a teacher to weave portions of existing audiovisual resources into a multimedia presentation that can be customized to meet an individual student's unique learning needs. Students themselves can create electronic class presentations as an alternative to written reports.

Administration

Special applications of productivity software have streamlined administrative functions. School or district offices maintain student, faculty, and staff records and manage administrative correspondence, record keeping, and communication with specialized programs incorporating word processing, data management, graphics, and telecommunications functions.

Communication

Parent-teacher communication can be made more dependable through electronic voicemail and telefacsimile (fax). A district-wide electronic mail system can do the same for the flow of information among administrators, teachers, students, and parents.

If every classroom is linked to the school library media center's automated catalog through a local area network, every student and teacher can identify relevant instructional resources without leaving the classroom.

A modem and communication software, along with a contract for Internet access, puts teachers and students into contact with experts next door or around the world. Satellite television receiving dishes not only bring whole courses into the classroom but provide opportunities for professional development.

Assistive Computing

Today, educators have a wealth of programs designed to facilitate teaching and learning, produce materials, and manage the process of education. Voice recognition and voice generation software enable students with exceptional learning needs to hear and to communicate, making it possible for them to participate more fully in the learning process. Text and graphics enlargement software help them see standard print. "Firmware" enables physically challenged students to operate computer keyboards and other instructional equipment. Some programs teach reading, listening, and thinking by allowing students to hear words pronounced, select words and phrases, and combine them into meaningful sentences.

Components of the Instructional Technology Framework: Using What Is Already in Place

Sometimes a technology upgrade is possible without replacing the entire system. Wise planners will look into classrooms and storerooms to see if existing hardware and software and other components of the technology framework are being used in the most efficient manner. Sometimes hopelessly obsolete computers are just taking up space and should be junked, but other times finding the right low-level task can extend their usefulness. Equipment is not the only concern here. Everything from storage rooms and closets to programs and staff persons can hold the potential for a more productive future. Here are some examples.

Equipment

Some microcomputers can be upgraded with memory expansion boards, increasing their application potential. Those that cannot might still have use as stand-alone workstations for word processing or other functions. Not all stand-alone computers need to store application programs on their hard drives. If individual computers are tied together through a school-wide network, programs and large data files can be stored on file servers (large capacity microcomputers) and shared with all the computers. Similarly, peripheral devices, such as printers, modems, and CD-ROM drives, connected directly to stand-alone microcomputers might be under-used. Connecting them to a network would make them accessible to many users.

Building-wide Communication Systems

It is possible that cabling already in place can serve a wider purpose or can carry additional signals. For example:

- A master antenna system to pick up and distribute local broadcast television throughout the building can operate as a self-contained one-building cable TV system.
- Coaxial cable can handle computer data transmission as well as video.
- Some cable TV companies make available live news services, such as *Ingenious*.
- Telephone wires can carry computer data but are more limited in capacity and speed.
- The telephone system enables live interactive two-way audio distance learning, linking students with teachers, scientists, children's authors, and so forth, throughout the district or the world.
- A qualified electronics engineer can assess capacity, prescribe connecting equipment, and design an appropriate network configuration.

The Library Media Program

As the school's information center, the library media program is the natural headquarters for information technology. Library media staff members may already be experienced in using electronic data transfer, and they will have a special interest in exploring the possibilities technology holds for teaching and learning. Given the right tools and sufficient capable staff, the library media program can create links for every classroom to the universe of information. Just as important, the library media staff can provide the selection, evaluation, acquisition, interpretation, and instruction needed to enable teachers and students to deal effectively with the large amount of information these links will make available.

Available Space

Space itself is a valuable commodity that could possibly be better used. Computer laboratories may already be in place. Adding network cards and wiring enables them to support additional applications. Rooms that are too small or under-utilized for some reason might house file servers and network equipment. Classrooms might be large enough to accommodate a cluster of computers. A production area outfitted for traditional audiovisual equipment might accommodate computer graphics and multimedia equipment without extensive remodeling. The faculty room could become a software exploration and production laboratory for teachers. Conduit or cable troughs might exist in crawl spaces, walls, and ceilings, enabling technicians to install additional cabling.

Interest from Local Business and Industry

Local or nearby businesses sometimes lend financial support to a technology upgrade if the owners of the firms or the directors of foundations associated with them are convinced that the advanced skills of graduates will be worth the investment. Contributions of time on the part of the businesses may be substituted for funding, especially if the companies have technology experts on their staff. If an outright donation of materials or services is not possible, a firm may be willing to barter its employees' expertise for educational services available from the school staff. Sometimes a firm may be able to donate useful supplies and equipment.

Popular Support

Community members may be willing to help in many different ways. Besides volunteering their time as computer lab assistants, community members might offer testimony at school board sessions or open meetings where the value of advanced technology is under discussion. Often, a person from business or industry is listened to more readily than a member of the faculty or school administration when the value of technology in the education of children is being promoted.

Technology Design Consultants

This list was prepared for persons seeking advice on the design of networks to facilitate transmission of voice, video, and data in school districts. These firms have been suggested by Wisconsin school district personnel, and their inclusion here does not imply endorsement by the DPI. The chart at the end of this appendix indicates which services these firms provide. The list includes firms that sell specific equipment or communications systems as well as those that are independent communications engineering consultants. Because changes in this field are frequent, persons who are thinking about contracting with these firms may want to ask beforehand what products or systems they sell or what companies they represent.

Anderson & Associates
Elwood Anderson
468 Gulch Ave.
Wisconsin Dells, WI 53596
(608) 253-6051

Brewster Software Systems
Robert Brewster
Route 1
Markville, MN 55048
(612) 242-3236

Command Computer Systems, Inc.
Mark Nelson
900 County Trunk Q
Fennimore, WI 53809
(608) 822-4444 or (800) 821-2663

Communication Technologies, Inc.
Neal McLain and Dick Gall
6213 Middleton Springs Dr.
Middleton, WI 53562
(608) 831-4636 or (800) 818-1511

Computer Integration Technologies, Inc.
Christopher Taylor
1990 Christensen Ave., Ste. EF
West St. Paul, MN 55118-4660
(612) 450-0333

Computerland
John Grupe
3610 Mall Dr.
Eau Claire, WI 54701
(715) 835-8082

Dascom Systems, Inc.
Dan Takkunen
475 Etna St., Ste. 11
St. Paul, MN 55106
(612) 776-8266

Education Technology Solutions
Susanne Andresen
609 Martin Ln.
Deerfield, IL 60015
(708) 537-1810

Elert & Associates
Technology Consultants
Gerritt Holgerson
672 N. 72nd St.
Milwaukee, WI 53213
(414) 257-3310

Epic USA, Inc.
Douglas Ruth and James Farstad
150 S. 5th St.
Minneapolis, MN 55402-4214
(612) 397-3142 or (800) 877-3742

Evans Associates, Consulting
Communications Engineers
Ralph Evans
210 S. Main St.
Thiensville, WI 53092
(414) 242-6000

Golden and Associates
Jane Pulvermacher
7621 Murphy Dr.
Middleton, WI 53562
(608) 836-8337 or (800) 236-[illegible]070

Gorham & Associates, Ltd.
William Gorham
678 Edie Ln.
Hudson, WI 54016
(715) 381-5600

Great Technologies
Andrew Miller
N497 Two Mile Rd.
Appleton, WI 54915
(414) 749-1926 or (800) 230-2724

Hundt Cabling Services, Inc.
Daniel Hundt
223 Woodland Ct.
Lake Mills, WI 53551
(414) 648-5071

Independent Telecom Consultants
Craig Aamodt
513 Wing Ln.
St. Charles, IL 60174
(708) 513-5114

Ironworks Software and Education
Jerry Unger
11254 N. Solar Ave.
Mequon, WI 53097
(414) 238-9858

Learning Technologies, Inc.
Gary Cummings
P.O. Box 8671
Madison, WI 53708-8671
(608) 825-2779

Memorex Telex Corp.
Todd Roberts
3720 N. 124th St., Ste. O
Wauwatosa, WI 53222
(414) 578-1914

Midwest Integrated Systems Laboratories, Inc.
J.W. Romlein
P.O. Box 29
Watertown, WI 53094
(414) 262-8000

Midwest Visual Equipment Company
Becky Sell
16908 W. Victor Rd.
New Berlin, WI 53151
(414) 784-5880 or (800) 878-5880

Network Resources, Inc.
Krasna Svoboda
14 W. Mifflin St., Ste. B
Madison, WI 53703
(608) 257-7050

Office Solutions
Dorie DeByle
6245 Packer Dr.
Wausau, WI 54401
(715) 848-3292

Office Technology
Jon Hoppe
1315 Gillingham Rd.
Neenah, WI 54956
(800) 729-4666

Office Technology
Barbara McMullen
2501 Church St.
Stevens Point, WI 54481
(715) 342-2900

PC Doctors, Inc.
Edison Blake
5930 Seminole Centre Ct.
Madison, WI 53711
(608) 276-5500

RMS Information Technology Integrators
Howard Soukup
135 Arlington Heights Rd., Ste. 104
Buffalo Grove, IL 60089
(708) 215-1661, ext. 352

S & R Telephone and Data
Scott Morrison
2238A Bluemound Rd.
Waukesha, WI 53186
(414) 798-0600 or (800) 236-2900

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Smith Micro Technologies, Inc.
Jim Smith
3435 Labore Rd.
St. Paul, MN 55110-5147
(612) 482-8718 or (800) 328-0929

Tallin Development Corp.
David Rebro
P.O. Box 92368
Milwaukee, WI 53202
(414) 543-0431

Thompson, Ross & Associates, Inc.
Ward Ross and John Thompson
7 Salt Creek Ln., Ste. 102
Hinsdale, IL 60521
(708) 850-3370

Todd Communications
Ken Daniels
6545 Cecilia Cir.
Minneapolis, MN 55439
(612) 941-0556

United Media Corp.
Andy Shapiro
75 E. Wacker Dr., 15th Fl.
Chicago, IL 60601-3708
(312) 443-0930

USConnect Milwaukee/
Micro Information Services, Inc.
Bill Koch
11425 W. Lake Park Dr., Ste. 900
Milwaukee, WI 53224
(414) 577-6600, ext. 349

Video Images, Inc.
Randy Drury
285 N. Janacek Rd.
Brookfield, WI 53045
(414) 785-8998

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	Analysis and Reporting of Current Status of Technology Use	Needs Assessment with Respect to Technology	District Planning for the Use of Technology	Design of: Communications Systems for Voice, Video, and Data (including the Internet)	Design of: Local Area Networks (LANs)	Design of: Wide Area Networks (WANs)	Design of: Video Transmission Systems Within a Building	Design of: Wide Area (multiple school districts) Distance Learning Networks	Design of: Telephone and Intercom Systems Within a Building	Design of: Wide Area Telephone and Intercom Systems	Design of: School Facilities to Accommodate Technology	Assistance in Writing Requests for Proposals or Bids
Anderson & Associates	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Brewster Software Systems		✓	✓	✓	✓	✓						
Command Computer Systems, Inc.	✓	✓	✓		✓							
Communication Technologies, Inc.				✓			✓	✓				✓
Computer Integration Technologies, Inc.	✓	✓	✓	✓	✓	✓						
Computerland		✓	✓	✓	✓	✓			✓			
Dascom Systems, Inc.			✓	✓			✓	✓				✓
Education Technology Solutions		✓										
Elert & Associates Technology Consultants	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Epic USA, Inc.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Evans Associates, Consulting Communications Engineers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Golden and Associates	✓	✓	✓	✓	✓	✓						✓
Gorham & Associates, Ltd.				✓		✓						
Great Technologies	✓	✓	✓									✓
Hundt Cabling Services, Inc.												
Independent Telecom Consultants	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ironworks Software and Education	✓	✓	✓		✓	✓						✓
Learning Technologies, Inc.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Memorex Telex Corp.	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Midwest Integrated Systems Laboratories, Inc.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Midwest Visual Equipment Company				✓	✓		✓	✓				
Network Resources, Inc.	✓	✓	✓								✓	✓
Office Solutions	✓	✓	✓		✓	✓					✓	✓
Office Technology		✓	✓	✓	✓	✓						✓
PC Doctors, Inc.	✓	✓	✓	✓	✓	✓						✓
RMS Information Technology Integrators				✓	✓	✓		✓				
S & R Telephone and Data	✓	✓	✓	✓							✓	✓
Smith Micro Technologies, Inc.												
Tallin Development Corp.												
Thompson, Ross & Associates, Inc.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Todd Communications							✓	✓				
United Media Corp.	✓	✓	✓	✓	✓	✓		✓			✓	
USConnect Milwaukee/Micro Information Services, Inc.	✓	✓	✓	✓	✓	✓					✓	✓
Video Images, Inc.	✓	✓			✓	✓	✓				✓	✓

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	Assistance in Bid Procurement Activities	Assistance in Analysis of Bids	Recommendation of Specific Hardware	Recommendation of Specific Network Software	Recommendation of Specific Application Software	Sales of Hardware (vendor representative)	Sales of Software (vendor representative)	Installation of Equipment	Installation of Building Wiring	Installation of Local Area Networks	Project Management	Assistance in Implementing a Project	Staff Training (professional development) in the Use of Technology	Technician Training
Anderson & Associates	✓	✓	✓	✓	✓									
Brewster Software Systems			✓	✓		✓		✓	✓	✓				✓
Command Computer Systems, Inc.			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Communication Technologies, Inc.	✓		✓			✓	✓				✓	✓		
Computer Integration Technologies, Inc.			✓	✓		✓	✓	✓	✓	✓				
Computerland		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Dascom Systems, Inc.			✓			✓	✓	✓			✓	✓		
Education Technology Solutions					✓		✓						✓	
Elert & Associates Technology Consultants	✓	✓	✓	✓	✓						✓	✓		
Epic USA, Inc.	✓	✓	✓	✓	✓						✓	✓		
Evans Associates, Consulting Communications Engineers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Golden and Associates	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gorham & Associates, Ltd.						✓		✓			✓		✓	
Great Technologies	✓	✓	✓	✓	✓						✓	✓	✓	✓
Hundt Cabling Services, Inc.									✓	✓				
Independent Telecom Consultants	✓	✓	✓	✓	✓						✓	✓		
Ironworks Software and Education	✓	✓	✓	✓	✓			✓		✓	✓	✓	✓	
Learning Technologies, Inc.	✓	✓	✓	✓							✓	✓		
Memorex Telex Corp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Midwest Integrated Systems Laboratories, Inc.	✓	✓	✓	✓	✓						✓	✓	✓	✓
Midwest Visual Equipment Company			✓	✓	✓	✓		✓		✓				
Network Resources, Inc.	✓	✓											✓	
Office Solutions			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Office Technology			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
PC Doctors, Inc.	✓	✓	✓	✓				✓	✓	✓	✓	✓		✓
RMS Information Technology Integrators									✓	✓				
S & R Telephone and Data			✓			✓			✓		✓			
Smith Micro Technologies, Inc.			✓	✓	✓	✓	✓	✓		✓				
Tallin Development Corp.				✓			✓	✓					✓	
Thompson, Ross & Associates, Inc.	✓	✓	✓	✓							✓	✓		
Todd Communications			✓			✓		✓	✓		✓	✓	✓	✓
United Media Corp.			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
USConnect Milwaukee/Micro Information Services, Inc.	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Video Images, Inc.			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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Questions to Guide the Architect Selection Process

These questions will help school districts judge how well an architectural firm can design schools that take full advantage of new and emerging technologies. Answers given by the firm's representatives will help members of the school district building committee assess the firm's knowledge of and experience with instructional technology and communications systems. The questions also call attention to the importance of having such expertise within the firm or obtaining it through specialized architects and engineers.

These questions are consistent with the Qualifications Based Selection (QBS) process offered by AIA Wisconsin, the Wisconsin chapter of the American Institute of Architects. (For more information, call [608] 257-8477.) One of the questions in the "Statement of Qualifications Information" form used in that process asks: *What experience does your firm and/or consultants have in designing comprehensive technological systems that support teaching, learning, administration, and communication in elementary and secondary schools?* The following questions build on this foundation.

The committee set up by the school district to review the architectural firms' qualifications and interview their representatives should include someone who specializes in instructional technology. While the use of electronic technology in school facilities is not new, technology grows more sophisticated every year.

Questions for the Interview

1. How would your designs for instructional and administrative spaces (classroom, studio, theater, distance learning room, auditorium, office) take full advantage of computer, video, audio, and other electronic technologies?

Analysis of response. The representative's answer to this question might focus on *educational theory* or on actual *design elements*. A complete answer would include both.

a. The *theoretical* approach would emphasize the potential that current and emerging technologies hold for improved teaching and learning, such as multisensory delivery of instruction, increased access to resources, improved motivation for learning, alternative ways for students to learn and to report what they have learned, different ways of testing, better communication, individualized learning, cooperative learning, and distance learning. This approach would also include management of nonteaching functions, such as pupil records, scheduling, accounting, and inventory, as well as the systems to handle public address, intercom, fire alarm, clocks, bells, duplicating, photocopying, and computer printing.

b. The *design elements* approach would emphasize the ways in which technology affects school design, citing the special characteristics of classrooms, offices, library media centers, study areas, labs, and meeting rooms, as well as the need for electrical power and light control and the importance of maintaining adaptability to changing needs.

Follow-up questions. The following may help to elicit more specific information.

a. Theory
- What changes are current and emerging technologies making possible for teaching, learning, and school administration?
- How do you envision teachers using computers in your designs?
- What kinds of audiovisual materials are accommodated in your designs?
- What role have you seen "distance education" playing in today's school designs?
- How have your designs improved communications in your school projects?

b. Design implications
- How would a "technologically correct" classroom look? Comment on the equipment, cabling, network connections, light control, flexibility.
- How would a "technologically correct" principal's office look? Comment on the equipment and so forth.
- How would your design accommodate the wires and cables (for example, conduit, trays)

needed to connect the learning spaces to resources and to one another?
- What spaces (for example, wiring closets) will be needed for communications network management equipment?
- How will greater use of technology affect electrical power needs?
- How does the new technology affect placement of key areas, such as the library media center, communications hub, teacher work area, distance learning studio, or classroom(s)?
- How would your design accommodate two-way interactive TV instruction?

2. What is your concept of a comprehensive technological system for managing instruction, administration, and communications in a school?

Analysis of response. The representative's answer should address the concept of *networks* for handling computer transactions as well as audio and video transmissions. Discussion should include:
- *Purposes* of networks (for example, expanding the range of resources, sharing resources, providing access to resources after hours).
- *Contents* (for example, hardware, wiring and cables, software).
- *Scope* (for example, local and wide area, building level, district level, CESA, state, global).
- *Patterns for connecting components* (for example, star, ring, tree, bus).

Follow-up questions.
a. How would your design provide access to *data* for administrative and instructional purposes
- within the school building?
- among the school buildings in the district?
- from sources outside the district?

b. How would your design provide access to a comprehensive range of *television programming sources* and video signals
- within the school building?
- among the school buildings in the district?
- from sources outside the district?

c. How would your design provide access to a comprehensive range of *radio and other audio* signals
- within the school building?
- among the school buildings in the district?
- from sources outside the district?

d. How would your design enable teachers to communicate by telephone, computer, or other electronic means with each other, with administrators, with students, with parents, with the community, and with colleagues across the state and country?

3. What is your concept of a school library media center that supports today's teaching and learning practices and provides efficient access to information in printed, audiovisual, and electronic formats?

Analysis of response. The representative's answer should address most of the *functions* that a library media center might be expected to support, the types of *resources* it would house, how *access* to those resources is provided through an *electronic catalog*, the *placement* and *size* of the library media center, how classrooms and offices might be *connected* to it electronically, its *staffing*, and how it provides access to resources *outside the school*.

Follow-up questions.
a. How would your design for a library media center use space to accommodate a variety of learning activities while assuring that they do not interfere with each other?

b. How do you see current and emerging technologies changing the ways library services are provided?

c. How would your design allow the library media program to take advantage of current and emerging technologies?

d. How would your design allow for access to multimedia learning resources in the library media center and throughout the building?

4. What knowledge or expertise do your lead project personnel have in educational, administrative, and communications software and its associated hardware?

Analysis of response. The representative's answer should demonstrate basic knowledge of information system management software, instructional software, scheduling software, basic spreadsheet and word processing software, as well as local and wide area networks to link workstations with each other in the building, across the district, and beyond.

5. What knowledge or experience do your lead project personnel have in distance learning applications and associated hardware?

Analysis of response. The representative's answer should incorporate a discussion of *lighting* (color temperature and intensity, ambient light), *acoustics* (noise levels, ambient noise from adjacent rooms, methods of testing, materials used, and methods taken to address audio problems), room *location* (isolation from high traffic areas), *function* (classroom versus studio), room *size* (considering activities, equipment, and seating arrangements), *wiring and cable runs, furniture, heating, ventilating, and air conditioning*.

The answer should also indicate knowledge of the differences between one-way and two-way interactive television systems as well as knowledge of the broad range of technology used in distance learning, such as audiographics, computers with modems, coaxial and fiber optic cable, and transmission by broadcast, microwave, and satellite systems.

6. What process does your firm use to find out how faculty, staff, and students hope to use technology in the new or remodeled facility and how the design might help or hinder effective use?

Analysis of response. The representative's answer should describe one or more methods (interviews, surveys, focus groups) for getting useful information from the future users of the facility. The answer might include a list of specific questions the architect will ask, topics for input, audiences to query (teachers, students, community), and ways to make the respondents feel comfortable about making suggestions.

7. Provide a resume of the information technology or telecommunications engineer that shows qualification in designing universal wiring projects, expanding upon the standards for telecommunications cabling used.

Analysis of response. The resume should reveal experience with school projects that have included wiring schemes for handling voice, data, and video for instructional and administrative purposes. A resume indicating work with local and wide area networks for voice, data, and video transmission within school buildings, within districts, and between school districts would be stronger.

Wires and Cables

Cables of some type are needed to connect the various components of a local area network (LAN) to user workstations.

Fiber optic cable is the fastest and has the greatest capacity and interference protection of all types of cable, but it is expensive, has special installation requirements, and needs signal translators at each end. Copper wire comes in several categories or levels and is the converse of fiber in terms of cost, speed, capacity, connectivity, and interference protection. Coaxial cable is somewhere in between in most of these areas.

The following facts about the various types of cable commonly used in networks for transmitting voice, video, and data have been developed in consultation with James Romlein, P.E., of MIS Labs, Watertown, Wisconsin.

1. Unshielded Twisted Pair (UTP) Copper Wire

Category 1. Used for analog and digital telephone and low-speed data applications, not generally used in LANs.

Category 2. Limited to data speeds of 4 megabytes per second (Mbps), not generally used in LANs.

Category 3. Four pairs of 100-ohm copper wires, each pair individually twisted together at a twist rate different from the other three pairs. The bundle is then encased in a PVC jacket. This cable can support an analog signal of 10 megahertz (MHz). Depending on the analog-to-digital encoding scheme, category 3 cable can support data transmission from 10 Mbps to 100 Mbps and is used for medium-speed data transmission in LANs.

Category 4. Similar to category 3 but supporting data transmission up to 16 Mbps. (This cable is hardly ever used and is no longer manufactured.)

Category 5. Similar to category 3, but the cables are twisted together at a much tighter twist rate, have better noise immunity and balance, and can carry an analog signal of 100 MHz. Because it supports up to 100 MHz even with a very low analog-to-digital encoding and can carry 100 Mbps of data transmission, this is often the cable of choice for horizontal connections within a building.

2. Shielded Twisted Pair (STP) Copper Wire

Two pairs of 150-ohm copper wires, each wrapped in metal shielding, then wrapped again in a woven metal shield and a PVC outer jacket; somewhat more resistant to interference than the UTP listed above.

3. Coaxial Cable

Single 75-ohm copper wire surrounded by a polyethylene insulator encased in metal sheathing and a plastic jacket, useful for transmitting voice and video along with data.

4. Fiber Optic Cable

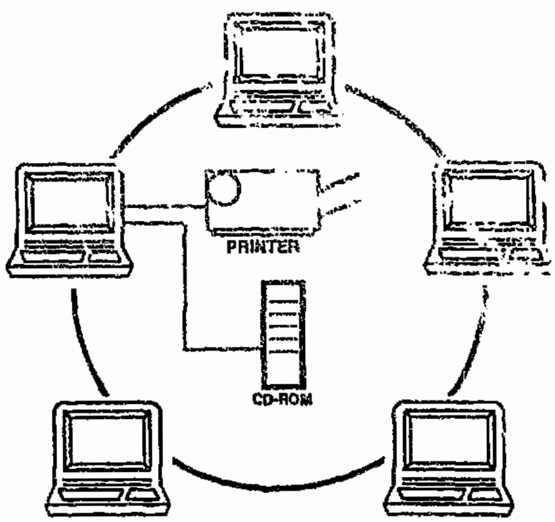
Both single-mode and multimode optical fiber cable are available, but multimode is generally used in horizontal telecommunications applications. Each single optical fiber is surrounded by thick plastic or gel, encased in a plastic jacket. Fibers are used in pairs, just as the copper cables. Because it is capable of transmitting combined voice, video, and data at speeds of 1 gigabyte per second with no danger of electro-mechanical or radio frequency interference, it is the preferred medium for LAN-to-LAN and building-to-building connections.

Network cabling is discussed in detail on pages 439-41 of Richard W. Boss's "Facilities Planning for Technology," *Library Technology Reports* 31.4 (July-August 1995).

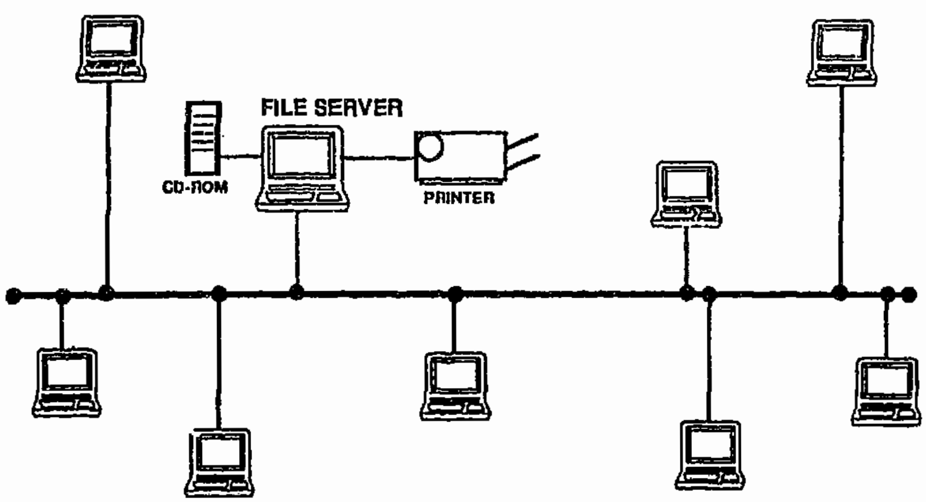
Regarding the cost of installing cabling, Curtis Priest commented in a January 8, 1996, note posted on the CoSN Internet Discussion List that, because of the high labor cost, planners might consider installing fiber optic cable along with copper wire, even though it will not be used immediately. He says, "The analysis in our MacArthur supported study on K-12 networking suggests that in situations where the labor cost of wiring is around fifteen minutes per foot (including those occasional places that run 2 hours/foot)—the labor cost is $11 per foot (at $45/hr) and at 36 cents per foot for single fiber optic cable and $1.02 per foot for 4 fiber, the cost of fiber is still only 10 percent of the labor cost. This strongly argues to run fiber whenever conduits and raceways are unfriendly, along with the cat 5 wiring for the future. Remember, cat 5 is good to about 100 Mbps while fiber is up near 100 Gbps. Of course, you leave the fiber unterminated because those costs are not small." <cosndisc@list.cren.net>

How the parts of a network connect is related to the type of cabling used, the distance one part is from the others, and the number of user stations to be served. Some topologies are faster; some use less cable; some are easier to reconfigure or add to. A network expert is best qualified to determine the right topology for a given installation and purpose. Following are examples of various network topologies. Drawings are reprinted with permission of the North Carolina Department of Public Instruction.

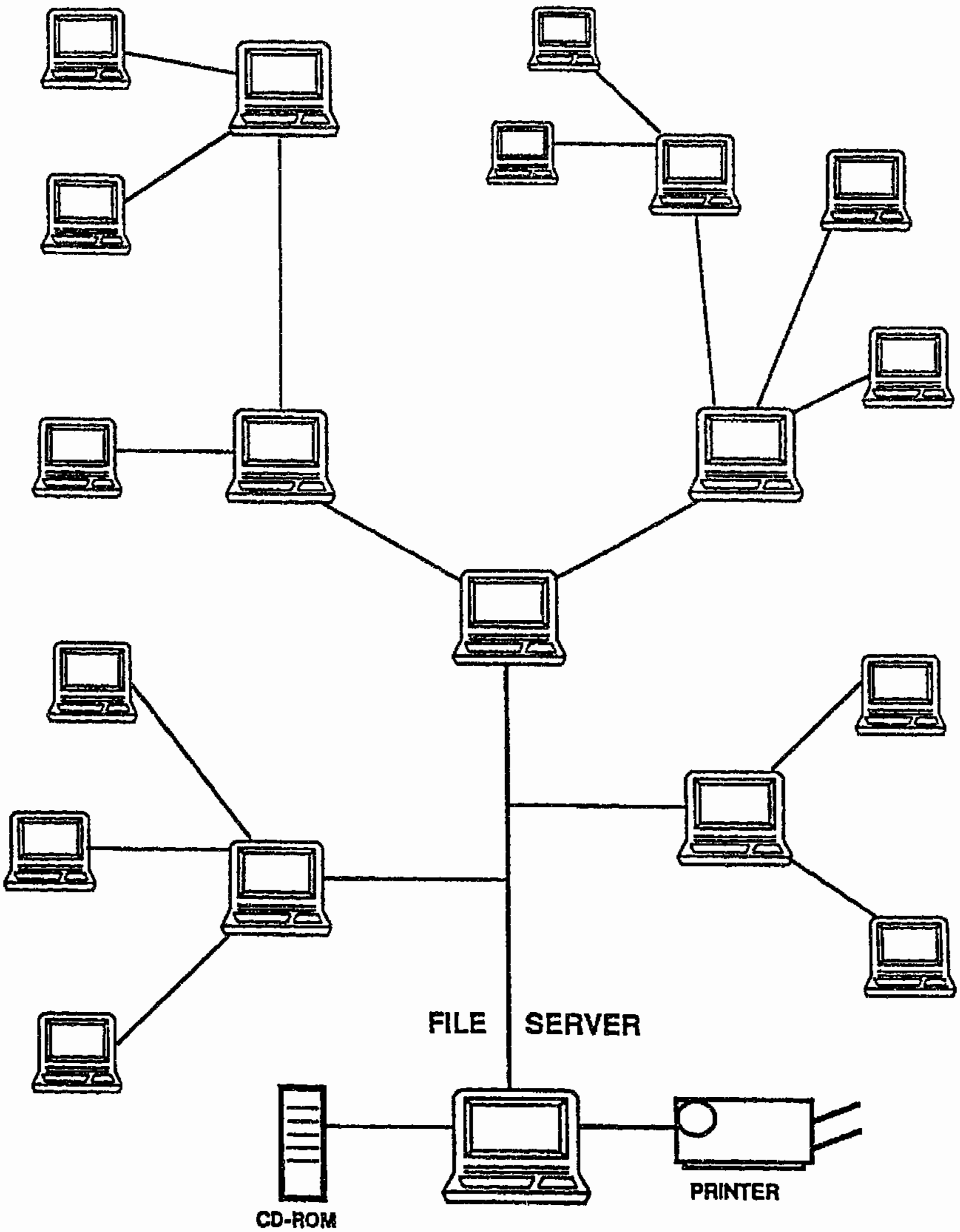
LAN Configuration—Ring Topology



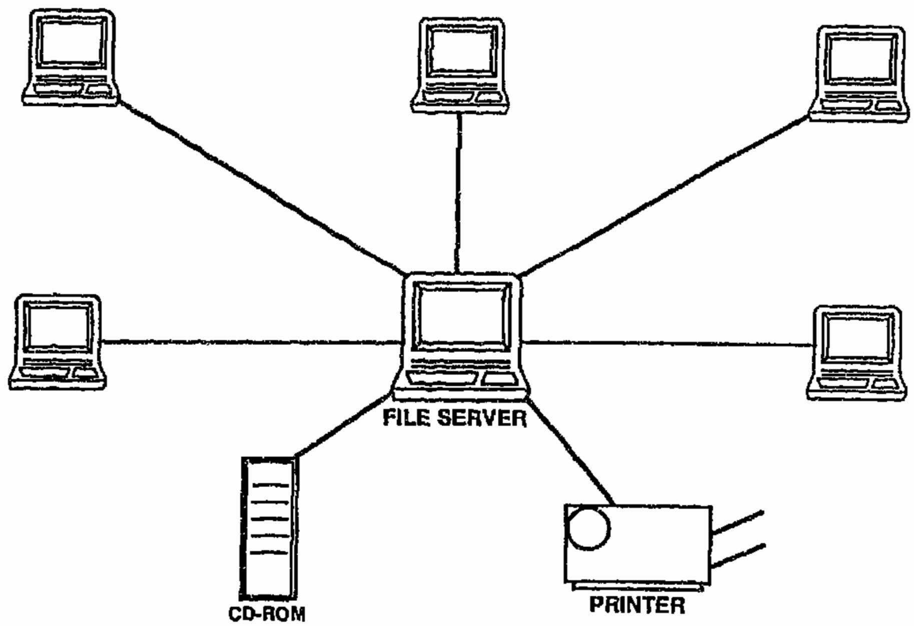
LAN Configuration—Bus Topology
(used with Ethernet)



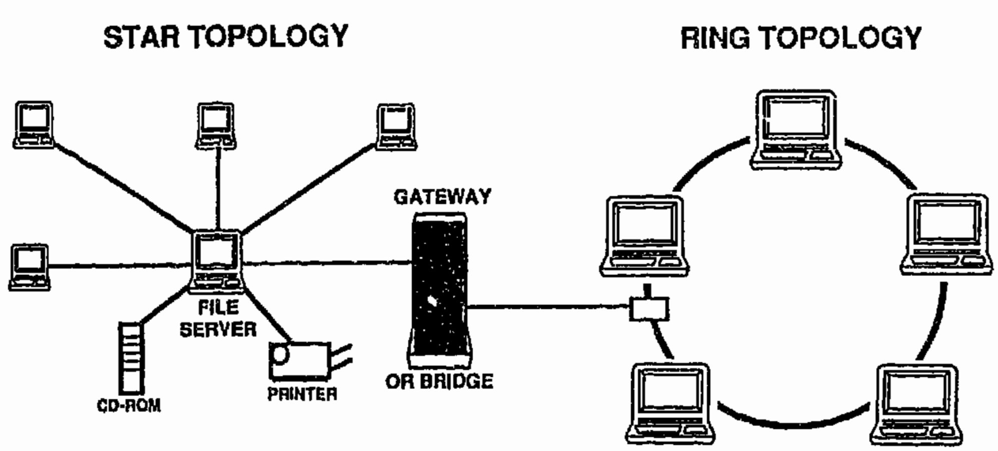
LAN Configuration—Tree Topology



LAN Configuration—Star Topology



Joining Topologies



Comments

Many thanks to the editors of *T.H.E. Journal* for granting permission to reprint the article that appears on the following pages, "Architecture and Costs of Connecting Schools to the NII," originally published in the October 1995 issue of *T.H.E. Journal*. While the model presented in the article is excellent for estimating the cost of connecting schools to the National Information Infrastructure (its primary topic), it is important for the reader to know that the numbers and types of equipment listed do not necessarily represent a recommendation of the Wisconsin Department of Public Instruction, nor do they represent common practice in Wisconsin public schools.

For instance, the three to five PCs per classroom would not accommodate the growing use of software in K-12 schools. The "Newswatch" article on page 7 of the January-February *MultiMedia Schools* reports that "the student-to-computer ratio continues to decrease to approximately one computer for every nine students." The "Newswatch" article also quotes a Quality Education Data survey report predicting that multimedia computers will increase more than 70 percent in 1996.

The model in this article also does not consider the need for students to have access to computing power after school hours. Some Wisconsin schools are purchasing laptop computers with internal modems to assure that students will be able to use them outside the normal school day to do their homework and continue their connection to school resources. In addition, they are purchasing computer-like keyboards with simple word processors built in for approximately $250 each to allow students to do keyboard practice and simple written composition at home.

The article also suggests some ways costs can be decreased, such as universities providing free technical support, volunteers installing LANs, and persons or businesses donating equipment and services. Planners should be cautioned that volunteerism of this sort is not always forthcoming, and sometimes it does not prove helpful in the long run. Persons willing to give of their time may not have the needed talent, and donated equipment may require additional expense to make it compatible with curricular applications and with the rest of the school's equipment.

Architecture and Costs of Connecting Schools to the NII

Mr. Russell I. Rothstein, Research Assistant, and Dr. Lee McKnight, Principal Research Associate
MIT Research Program on Communications Policy Massachusetts Institute of Technology, Cambridge, Massachusetts

Universal connection to the National Information Infrastructure (NII), it is presumed, will facilitate educational reform within schools and communities. Several developments suggest this:

- The federal government is committed to having every classroom in the U.S.A. connected to the NII by the year 2000;
- A number of telephone and cable companies have announced plans to connect schools in their service areas at low or no cost;
- Modern, high-speed networks have been installed at a number of progressive, pioneering K-12 schools;
- The Internet, a global network of networks that connects to an abundance of educational resources, is experiencing phenomenal growth.

However, to date, there is relatively little known about the costs for connecting schools to the information infrastructure. Even though exact costs are unknown, they are expected to be significant. To reduce these costs, a variety of approaches are being tried.

Some states have implemented the cost-saving strategy of purchasing telecommunications equipment and services for all schools in the state. For example, North Carolina has saved its schools 20 percent to 50 percent on certain items. Some states have passed legislation permitting the state Public Utility Commission to set preferential or fixed intra-state rates for educational institutions.

Our research suggests that a number of programs would have a significant impact on the total costs of connecting to the NII. For instance, if all schools coordinate purchasing at the state level, cost savings will exceed $2 billion. Colleges and universities often have the resources to provide technical support to K-12 schools. If a nationwide program were instituted, potential savings would be $800 to $1,800 million.

If schools were given free Internet connectivity, the total annual costs for school Internet connections would be reduced from $150 to $630 million. But costs for telecommunications lines and services represent only 11 percent of the total costs, and hence reductions will have a limited impact.

Finally, as the costs of networking schools is better understood, a new question arises: How will these costs be financed? Many states have programs to fund networking in schools. The federal government has a role, although it must become more flexible and coordinated. However, as Vice President Gore continues to state, the NII will be built by the private sector. A number of states have initiated cooperative ventures between businesses and schools. An expansion of these programs may be the key for successfully connecting K-12 schools to the NII.

But connection alone is not enough: we report below on our finding that support and training together comprise 46 percent of the total costs of networking schools.

Scope of K-12 Networking

The model of school networks presented follows the Internet-networking model, by which schools have digital, data connections that transmit and receive bits of information. The models do *not* include analog video point-to-point networks or voice networks and voice-mail systems. Audio and video functions are possible in digital format over the Internet, but many schools will still use separate video and voice networks. Costs for these systems are important, but are not covered in this article.

It should also be noted that although voice and video networks have been separated out from this report, schools should not consider these three types of networks to be wholly distinct. Some schools have integrated their voice and video networks with their data network. Sharing resources between the multiple networks can be effective in providing significant cost savings. At a basic level, it must be understood that as a school installs a LAN and puts computer data connections in every classroom, there are little added costs to also concurrently install other types of connections, including telephone lines.

Technology Standard for Connecting to the NII

As described in Information Infrastructure Task Force (1994), the NII "promises every . . . school . . . in the nation access anywhere to voice, data, full-motion video, and multimedia applications . . . . Through the NII, students of all ages will use multimedia electronic libraries and museums containing text, images, video, music, simulations, and instructional software." The following requirements outline what the model presumes is needed in order to have full connection to the NII:

A LAN within the school with connections to multiple machines in every classroom. The power of the network is greatly enhanced with more access points throughout a school. A classroom with one connection is not conducive for use of network applications in a class of 20 or 30 students. Telecommunications will not be a tool for systemic educational reform until network connections are replete throughout a school.

A connection from each school to a community hub. From two to ten schools should connect to a single hub, depending on the size of the schools. In most cases, the hub will reside at the district office. However, where there are many schools in a single district, then schools should be clustered into sets of four to six. Each of these school-clusters will have a group hub, probably at the district office, which will contain the center of the network for those schools. The rationale for the use of this architecture is described below.

A connection between the school LAN and the district office hub. With this configuration, every classroom has a connection not only to every other class in the school but also to the central district office.

A connection from the school district office to a community-, state-, or nationwide Wide Area Network (WAN). This link will allow all schools to connect to the WAN. The

Internet is a good example of such a WAN and will be used throughout this report as a model and precursor for the NII.

Sufficient bandwidth for these connections. With a high-bandwidth connection, users in schools can make use of graphical applications (like Mosaic) and limited video service (like CU-SeeMe and MBONE). For most districts, the minimum bandwidth, or bit-speed, that will support these services is 56,000 bits per second (56 Kbps). Thus the connection between the school and the hub must be at or above this level. For the connection from the district office to the Internet, a broader pipeline is necessary because all of the schools in the group connect to the Internet through this line. The suggested minimum bandwidth for this connection is 1,500,000 bits per second (1.5 Mbps), also known as a "T1 line."

Symmetric, bi-directional access to the WAN/Internet. It is important that the connection to the school allows information to flow both in *and* out at the same rates. In this way, students can become both consumers and providers of information over the network.

Adequate remote dialup facilities. With a sufficient number of modems and phone lines, faculty, students and parents can gain access to the school system remotely on weekends and after school hours.

Use of established and tested technologies. Schools have benefited most from mature technologies that have been well tested in the marketplace. Cutting-edge technologies have not been as successful in schools due to their inherent instability and the large amount of resources required to support them. The models assume the use of mature technology and transmission media. Newer technologies such as wireless and coax-fiber hybrid systems are not considered in this study. However, given the rapidity of technological change and marketplace evolution for networking products and service , wireless and cable alternatives should be evaluated in future research.

Architecture of the District Network

The basic network architecture for these models follows the "star" configuration, similar to that used in the nationwide telephone network. In the phone network, residential telephone lines in an area are directly connected to a single district office. In the school network, each school building is connected to the school central hub. In most cases, the district office will serve as the central hub. However, in cases where there are very few or many schools in one district, then alternative sites must be chosen.

The rationale for adopting this architecture is that when many schools are connected through a single hub, then costs can be aggregated among them. This gives schools stronger purchasing power as equipment purchases are aggregated by the school district for volume discounts. It also allows schools to share resources—such as the data line to the Internet, training programs and full-time support staff—that each school might not be able to afford individually. Thus, there are costs both at the school and at the district level for networking schools across the country.

A second rationale for adopting a star architecture is that it is confluent with the administrative/bureaucratic design of the school system. Individual schools report to a school district office, which in turn reports to state education offices. In the network design, schools connect to the district office hub, which in turn connects to a statewide (or national or global) network.

Cost Areas

The cost models presented in this article include four types of costs: hardware, training, support, and retrofitting. Items included in these categories are summarized:

- Hardware: wiring, routers, servers and PCs, including installation, maintenance and service of the hardware, and telecommunications lines.
- Training: training of teachers and other school staff to use the network.
- Support: technical support of the network.
- Retrofitting: modifications to the school facility to accommodate the telecommunications infrastructure. This may include costs for asbestos removal (where applicable), electrical systems, climate control systems, added security (locks, alarms, and so forth), and renovation of buildings to accommodate network installation and operation.

A cost area *not* included in the models is educational software. "Freeware" versions of many popular Internet applications exist, however, other educational software may be desired by particular schools. Economic analysis of such software costs and their evolution in network scenarios is needed.

Four Different Technology Models

Following is a brief description of four ways to achieve connectivity to the NII. Inherent costs are noted; details are provided later in this article.

Model one: Single PC dialup. This model represents the most basic connectivity option for a school. The school has no internal LAN within the building. There is a single connection to the district office over a modem and standard phone line. Only one person may use the connection at any time.

Model two: LAN with shared modem. The difference between this model and the former one is the existence of the LAN within the school. By connecting the modem to the LAN, every computer on the network has access to the Internet. However, this model supports only a few users at a time, since it is limited by the number of phone lines going out of the school. As in the first model, users of the system can only utilize text-based applications over the Internet (for example, e-mail, telnet, gopher).

In this model, there is now a cost for the LAN. This model assumes the use of copper wire (category 5) as the medium for the network since it is the most affordable and scaleable option for schools in 1994. The costs for the wiring and network cards run $100 to $150 per PC connected. Including costs for the accompanying hardware and labor, costs per PC are $400 to $500. Therefore, for the school model with 60 to 100 connected PCs (three to five PCs per classroom for 20 classrooms), the total LAN costs are $20,000 to $55,000.

Model three: LAN with router. The main difference between this model and the former one is the existence of a router in place of the modem. With the router, multiple users of the LAN may access the Internet concurrently. Again, people can use text-based applications over the Internet, but have no real-time access to video or graphics.

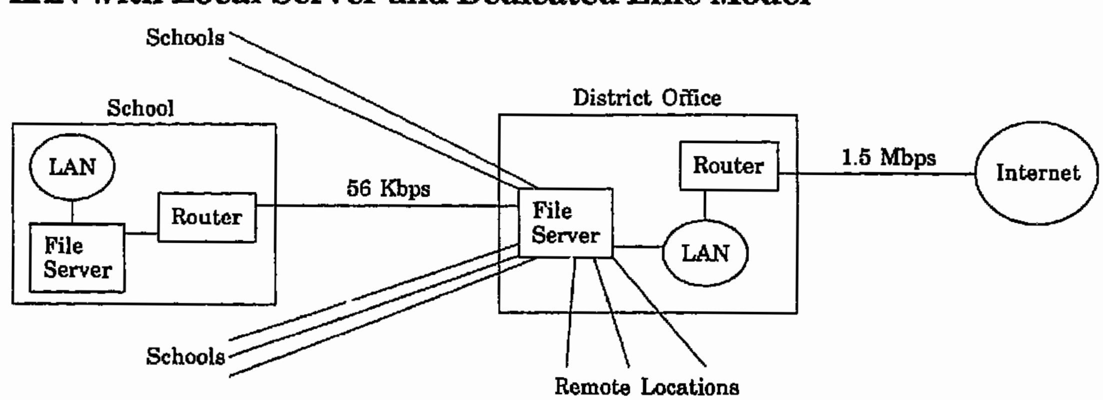
Since the router allows multiple users of the system, there is an opportunity to expand the entire network infrastructure. With this infrastructure, it is reasonable to support one PC in every classroom. Therefore, there is a requirement to purchase 15 additional PCs for the average school to use in addition to its small initial stock of TCP/IP-compatible machines. It is assumed that the purchasing of these PCs is done at the district level in order to negotiate better rates ($1,000 to $2,000 per PC).

Support and training costs are higher since there are additional users of the system. There are additional dialup lines required to accommodate remote access. There are also significant retrofitting costs for the electrical system, climate control system and enhanced security.

Model four: The preferred strategy LAN with local server and dedicated line. The primary difference between this model and the former one is the existence of a file server at the school. (See figure 1.) The on-site server allows

Figure 1

LAN with Local Server and Dedicated Line Model



Source: U.S. Department of Education, 1994.

much of the information to reside locally at the school instead of at the district office. This feature provides better performance since more data does not need to be fetched over the network. Additionally, the local server allows school administrators to exercise greater control over the information that flows in and out. Higher speed links from the school enable the use of limited video, graphical, and text-based network applications.

In this model, virtually the entire school is supported on the network. As a result, the training program is extensive, and the support team is well staffed. Costs of the connection to the Internet are also higher due to the larger bandwidth. Significant retrofitting costs are incurred for the electrical system, climate control system, and better security. A range of costs for an average size school to attain this level of technology is listed in figure 2's table.

Figure 2

LAN with Local Server and Dedicated Line Model Costs

	Low	High
School Costs		
One-time installation costs		
Local Area Network (LAN)	$20,000	$ 55,000
Personal computers (60 machines)	60,000	120,000
File server	4,000	15,000
Connection to hub/district office (56Kb)	500	2,000
Router and CSU/DSU	2,600	5,000
Retrofitting (major)	10,000	25,000
Total	$97,100	$222,000
Annual operating costs		
Replacement of equipment	$ 3,000	$ 8,250
Connection to hub/district office (56Kb)	1,000	5,000
Total	$ 4,000	$ 13,250
District Office Costs		
One-time installation costs		
File server	$ 2,000	$ 15,000
Router	2,000	5,000
District LAN	2,000	5,000
Data line to WAN/Internet (1.5 Mbps)	1,000	5,000
Dialup capabilities (20 lines)	16,000	32,000
Training (40 to 50 staff per school)	50,000	150,000
Total	$73,000	$212,000
Annual operating costs		
Internet service (1.5 Mbps)	$10,000	$ 42,000
Dialup lines	3,000	5,000
Support (2 to 3 staff per district)	66,000	150,000
Training	15,000	35,000
Total	$94,000	$232,000
Total U.S. One-time Costs	$9.35 B	$22.05 B
One-time cost per student	$212.47	$501.14
Total U.S. Annual Costs	$1.75 B	$4.61 B
Annual cost per student	$39.77	$104.69

Source: U.S. Department of Education, 1994.

Using the Models to Estimate Costs

These four models are representations of the network technology used in schools. While a level of complexity and detail is omitted, the simplicity is helpful because they encompass broad cross-sections of network and school configurations. The models provide a clearer view of the costs and choices for networking K-12 schools.

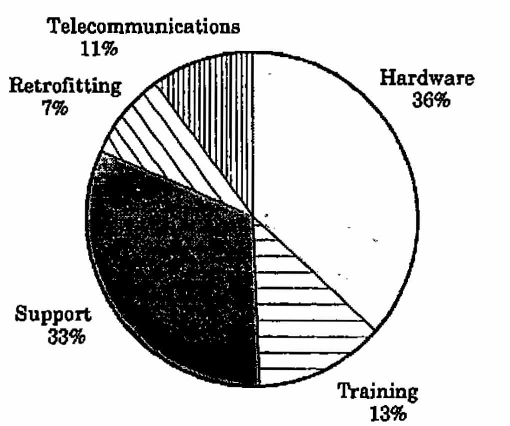
Using this model as a baseline for connecting to the NII, these figures then become indicative of the costs of connecting K-12 schools across the country to the NII. These numbers indicate that there will be $9.4 to $22 billion in one-time costs, with annual maintenance costs of $1.8 to $4.6 billion. At the per-pupil level, this is equivalent to $212 to $501 in one-time installation costs and an ongoing annual cost of $40 to $105.

In this model, hardware is the most significant cost item for schools. However, most of the cost is for purchasing PCs. The value of PCs in schools goes well beyond their use as networking devices. Therefore, the "real" costs for PC purchases should be allocated across other parts of the technology budget, not only to the networking component. If this is done, then hardware costs for connecting schools to the NII drop considerably.

If the high startup costs are amortized equally over a five-year period, then the breakdown of costs during the first five years, excluding PC purchases, is as shown in figure 3's pie chart.

Figure 3

Breakdown of Costs for Baseline NII Connectivity



Source: MIT Research Program on Communications Policy, 1994.

Costs for support of the network represent about one-third. Support is a vital part of any successful implementation of a school network, and its costs *must* be factored into the budget. Support and training together comprise 46 percent of the total costs of networking schools.

Finally, it is important to note that the costs for telecommunications lines and services represent only 11 percent of total costs. This amount is *lower* than those assumed by much of the technology community, including telecommunications service and equipment providers.

To put all of this into perspective: Total U.S. expenditures on K-12 education in 1992-93 totalled $280 billion. Total one-time costs for the fourth model described above represent 3 percent to 7 percent of total national educational expenditures. The ongoing annual costs represent between 0.6 percent to 1.6 percent of total national educational expenditures.

Potential Impact of Initiatives on Costs

Much more can be done by the government and the private sector to significantly mitigate the costs that schools face in order to connect to the NII. This section examines some possible programs and their impact on the costs to schools.

Preferential telecommunications tariff rates are instituted for schools.
Estimated savings: $89M to $218M (one-time)
(30 percent reduction) $39M to $150M (annual)

Estimated savings: $179M to $435M (one-time)
(60 percent reduction) $78M to $300M (annual)

All technology purchasing is done at the state level. Figures are based on an average of 30 percent discount across all 50 states.
Estimated savings: $1.9B to $4.1B (one-time)
$45M to $189M (annual)

Universities or other institutions provide technical support to schools. It is assumed that schools will be able to function with 80 percent less support staff than would be required without university support.
Estimated savings: $790M to $1.8B (one-time)

Teachers trained on their own time. If teachers agreed to attend classes on their own time, the only cost would be for the trainer.

Estimated savings: $0 to $1.5B (one-time)
$0 to 300M (annual)

LAN installed by volunteers. If groups of parents and community members offer to provide labor at no cost, schools would reap significant savings.
Estimated savings: $1.1B to $3.1B (one-time)

Personal computers are donated to schools. The success of a donation program depends on the quality of the equipment given. Schools will require fairly modern machines to run networking software. Donations of obsolete or incompatible equipment may be very costly to schools.
Estimated savings: $5.1B to $10.2B (one-time)

Network routing equipment are donated to schools. This program is similar to a PC donation program. The savings are lower, however, since the routing equipment is less expensive.
Estimated savings: $221M to $425M (one-time)

Network servers are donated to schools. Again, this is similar to the PC donation and router donation programs.
Estimated savings: $370M to $1.5B (one-time)

Internet connectivity is free to schools. This could be arranged either by provision from an Internet service provider or from a local university or community college that has its own Internet connection.
Estimated savings: $150M to $630M (annual)

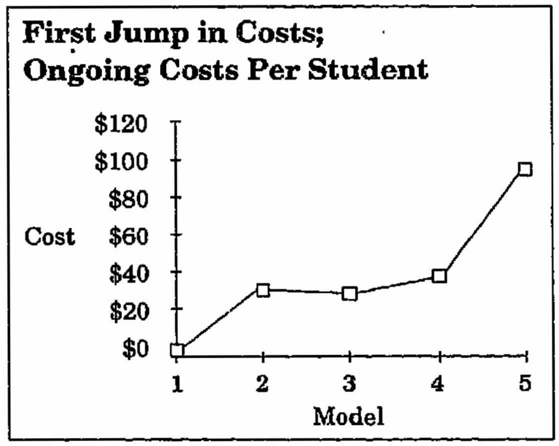
Conclusions

With a clearer picture of the costs for connecting schools to the NII, a number of conclusions may be drawn.

The costs to network a school are complex. It is not simple to estimate the costs for a particular school. Costs for most schools will fall into a bounded range, but each particular school will vary greatly depending on its individual needs and characteristics. While this article seeks to put bounds on cost figures, the numbers are rough estimates at best.

Network hardware cost is only a small fraction of the overall costs for connecting to the NII. Initial training and retrofitting are the largest one-time costs for starting the network. Costs for the wiring and equipment are typically not as high. Support of the network is the largest *ongoing* annual cost that schools must face.

Figure 4



Source: MIT Research Program on Communications Policy, 1994.

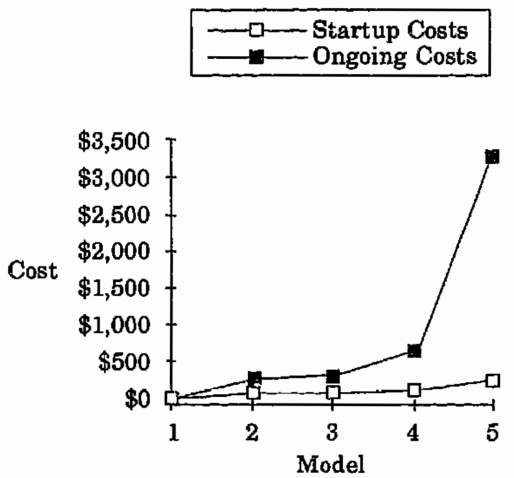
There are two major jumps in the costs to network a school. The first jump in cost arises when the school installs the LAN. (See figure 4.) At that point the school and district must pay for installation ($20,000 to $55,000 per school) and employ full-time support staff ($60,000 to $150,000 per district).

The second jump arises if and when a school decides to purchase computers for all students to use. The number of networkable PCs in 1994 is inadequate for most schools; hundreds of thousands of dollars would be needed to provide multiple PCs in every classroom. Also, many schools will need major electrical work (possibly $100,000 plus) to support the increased number of PCs. In the intermediate stages between these jumps, the costs are incremental and relatively small.

Startup costs for the network increase at a faster rate than the annual ongoing costs as the network complex increases. In the less complex models, the one-time startup costs are two to three times the annual ongoing costs of the network. However, for the more complex models (models four and five) the one-time costs are five to 15 times the costs to start the network. These differences are illustrated in figure 5's graph.

Figure 5

Second Jump in Costs; Startup and Ongoing Costs Per Student



Source: MIT Research Program on Communications Policy, 1994.

The divergence indicates that the most significant hurdle that a school will face is the initial investment costs in the network and computers. Dispensers of educational funding should be aware of this trend, so that they can help schools overcome this initial barrier. Schools should be given flexibility to amortize initial costs in order to spread the burden over a number of years.

Costs are significantly reduced when aggregated at the district and state levels. Schools stand to save a lot of money by pooling resources and purchasing power with other schools in the district and at the state level. When schools share a high-speed data link or support staff, the per-school costs drop considerably. Schools in North Carolina and Kentucky, for instance, have saved 20 percent to 50 percent by purchasing services and equipment at the state level.

Education initiatives of telephone and cable companies will have a small impact on the total costs to schools. The free telecommunications services currently offered by these companies are only a small piece of the total cost for successfully networking schools. However, schools would greatly benefit from the establishment of state trust funds or other cooperative efforts as included in some plans. The benefits of these programs are more difficult to quantify but are significant, nonetheless. They have the potential to garner support and consensus for connecting schools to the NII. In contrast, the highly touted free connections and free telephone services are not as valuable to schools.

Further research on the costs of wireless and cable Internet access methods for schools is recommended to elucidate the costs and benefits of these approaches. In addition, the issue of software and equipment cost accounting require further analysis. We hope that this preliminary assessment of the costs of connecting schools to the NII can provide a point of departure for analysis of these and other more detailed models of NII connectivity for schools.

Reference

Rothstein, R. *Connecting K-12 Schools to the National Information Infrastructure: Technology Models and Their Associated Costs.* U.S. Dept. of Education Working Paper, 1994.

This paper is based on a report prepared when Russell Rothstein was Visiting Researcher at the Office of Educational Technology in the U.S. Department of Education in 1994. Further work was supported by ARPA contract N00174-93-C-0036 and NSF grant NCR-9307548 (Networked Multimedia Information Services). The invaluable help of Dr. Linda Roberts, U.S. Department of Education, and Joseph Bailey, Thomas Lee and Sharon Gillett, MIT Research Program on Communications Policy, is acknowledged.

The Technologically Current Classroom: Some Features You Might Expect

1. Installed equipment, including
- pull-down projection screen
- VCR
- two wall-mounted 25-inch-minimum video/computer monitors or one video/computer projector
- computers for each student and teacher
- modem

Additional items might include a computer printer, a scanner, and a video camera.

2. Outlets or junction boxes to connect
- coaxial cable
  - — linking classroom to central video distribution (two-way)
  - — linking classroom VCR to two monitors or projector
- wire or cable
  - — for voice transmission (telephone, intercom, and distance education)
  - — for data transmission, connecting computers, file servers, printers, CD drives, modems, and other devices within the classroom or from the classroom to the library media center (LMC), office, schools, the world
  - — for clock, bell, and fire alarm systems

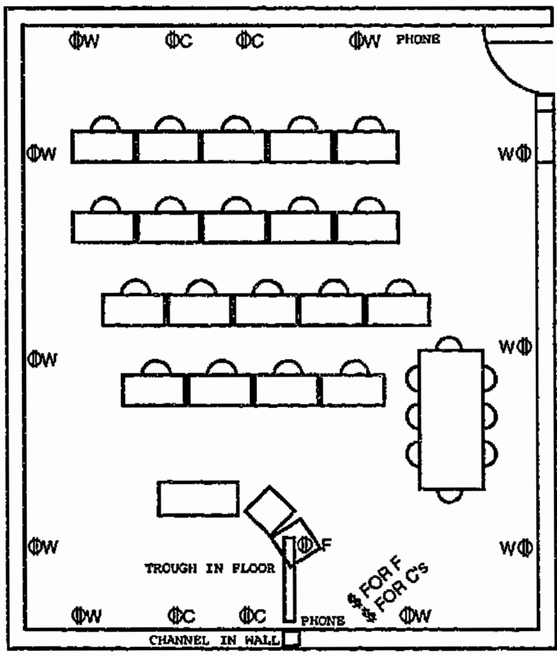
3. Electrical power service, including
- one quadplex outlet in the center of the typical teaching wall
- at least one duplex outlet on each wall with outlets no more than 10 feet apart
- multiple circuits
- clean power (no interference or power spikes)

4. Access to local and wide area networks (LANs and WANs) for transmission of voice, video, and data signals. Although they will not be visible, the components necessary to provide this will include cabling, controllers, routers, bridges, and gateways, required for connecting computers with file servers and other resources; as well as transceivers, repeaters, amplifiers, satellite dishes, and antennas.

5. Artificial light control to permit switching off the bank of lights nearest the teaching wall

6. Flexibility of design permitting adaptability to changing technologies, including
- movable walls
- wiring ducts and troughs in floor or ceiling
- generous supply of power circuits and outlets

Examples of Distance Learning Classroom Designs



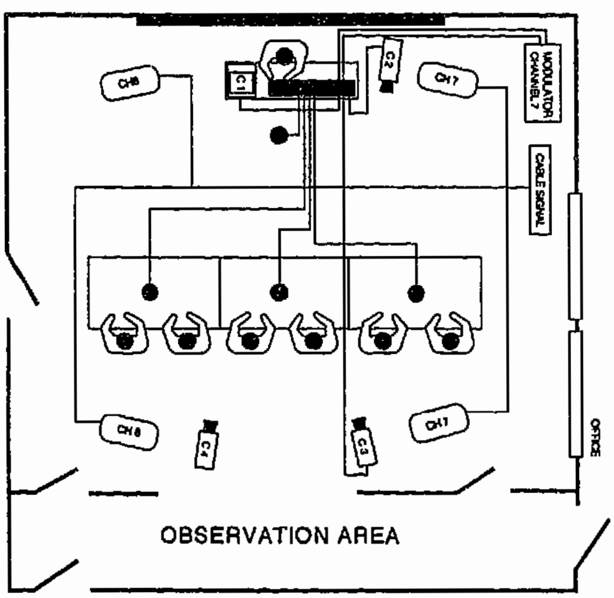
Example 1

Specifications

1. No windows
2. Dark wall covering (less than 50 percent reflectance)
3. Quiet HVAC system
4. Soundproofing to limit noise into room
5. Carpeted floor
6. Telephone jacks in front and rear

Key

ⓘ W – Wall outlet
ⓘ C – Ceiling outlet
ⓘ F – Floor outlet
$ – Switch



Example 2

Key

C1 – Overhead camera
C2 – Student camera
C3 – Teacher camera
C4 – Other camera

Monitors

1 shows camera 1
2 shows camera 2
3 shows camera 3
4 shows VCR
5 shows actual program

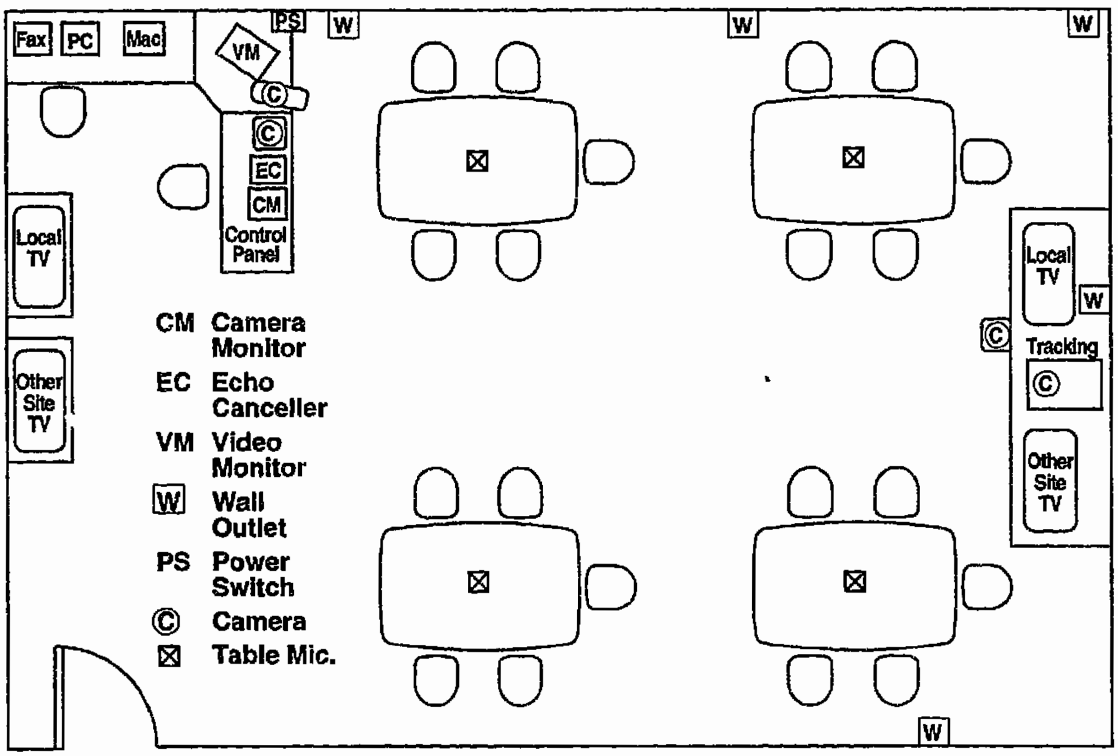
Routing

Microphones: into switcher, then into modulator

Cameras: into switcher, then into modulator

Cable TV output: directly into Channel 7 and 8 monitors

Example 3


Fax
PC
Mac
PS
W
W
W
VM
C
C
EC
CM
Control Panel
Local TV
Other Site TV
CM Camera Monitor
EC Echo Canceller
VM Video Monitor
W Wall Outlet
PS Power Switch
C Camera
Table Mic.
Local TV
W
C
Tracking
C
Other Site TV
W

Schools Designed to Accommodate New Technology

Many Wisconsin school facilities accommodate technology effectively. The following examples represent districts of different size and location.

Appleton Area School District
P.O. Box 2019
Appleton, WI 54913

Thomas Scullen, Administrator
Phone: (414) 832-6126
James Klein, Curriculum and Instruction Coordinator (West Cluster)
Phone: (414) 832-4397

Features: Two elementary schools have a local area network and have automated the library media centers. The district-wide library automation system provides centralized cataloging and processing. A new high-tech high school has library media center catalog terminals in two teacher common planning areas. An Ameritech Super Schools fiber optics link connects two high schools.

CESA 12
618 Beaser Ave.
Ashland, WI 54806

Fred Schlichting, Administrator
Phone: (715) 682-2363

Features: The Northern Wisconsin Educational Communications System began in October 1992, connecting nine locations across a 400-mile fiber optic network (Ashland High School, Bayfield High School, Washburn High School, CESA 12, and the five Wisconsin Indianhead Technical College campuses). Drummond High School and South Shore High School were added in 1993, UW–Superior in 1994, and Lac Courte Oreilles Community College and Winter High School in 1994, expanding the number of sites to 15 and the network area to over 972 miles.

Clintonville School District
26 Ninth St.
Clintonville, WI 54929

Jerry Schoenike, Administrator
Phone: (715) 823-7206

Features: A fiber optic cable system links seven small, rural school districts to distribute full-motion interactive video distance learning. It provides these sites with satellite-delivered instruction and fiber-based connection to the Internet.

Menomonie School District
718 N. Broadway
Menomonie, WI 54751

David Smette, Administrator
Phone: (715) 232-1642

Features: The district is building a wide area network to provide access to voice, video, and data resources. Students and staff currently connect to the Internet and other electronic resources from the high school and middle school libraries. Student electronic communication is possible through Global Schoolnet resources. Computer labs are used in the elementary and middle schools and in the technology, business, writing, and all-purpose areas of the high school. A district technology team is establishing guidelines for long-range technology planning.

Middleton-Cross Plains
7106 South Ave.
Middleton, WI 53562

Steven Koch, Administrator
Phone: (608) 828-1600
Conrad Wrzesinski, Computer Coordinator
Phone: (608) 828-1600

Features: Access to the World Wide Web is available in the library media center in each school. Teachers use Internet e-mail and receive television programming via satellite, ITFS, and cable television. On-site video production is possible at any school in the district.

Oregon School District
200 N. Main St.
Oregon, WI 53575

Linda K. Barrows, Administrator
Phone: (608) 835-3161
Frances Bogus, Library Media Director
Phone: (608) 835-3161
Mike Way, Computer/Technology Coordinator
Phone: (608) 835-3161

Features: A formal planning process has guided technology use over the last eight years. A wide area network using fiber optic and coaxial cable, multi-line modems, satellite receivers, and ITFS downlinks brings telephone, data, and audiovisual information to every room in all schools. The network supports MS-DOS, Windows, and Macintosh platforms and connects with an AS/400 system for student and financial records management and a 56K link to the Internet. The library media programs, food service, and transportation systems are fully automated.

Plymouth School District
125 Highland Ave.
Plymouth, WI 53073

Paul C. Brandl, Administrator
Phone: (414) 892-2661
Gary Vance, Library Media Director
Phone: (414) 893-6911

Features: Careful planning has assured that technology is perceived as a means rather than an end in itself. A comprehensive staff development program has prepared all teachers to use technology wisely. The district uses satellite, ITFS, and cable television for distance learning.

Spencer School District
300 School St.
Spencer, WI 54479

Larry Stordahl, Administrator
Phone: (715) 659-5347
Carolyn Sauer, Library Media Director
Phone: (715) 659-4211

Features: Two-way television courses are shared with Granton, Stratford, Loyal, and D.C. Everest school districts and Northcentral Technical College. The district also uses several other distance learning technologies, including satellite television, two-way audio, and computer conferencing.

Verona School District
700 N. Main St.
Verona, WI 53593

Robert Gilpatrick, Administrator
Phone: (608) 845-6451, ext. 164
Steven Lanphear, Educational Technology Coordinator
Phone: (608) 845-6451, ext. 132

Features: Extensive local area networks connect classrooms in individual schools. In the high school a master video switching system links video, CD-ROM, laserdisc, and satellite resources to every classroom. A wide area network connects the local networks to the online library catalog, CD-ROM library resources, an Apple Internet Search Server, direct Internet access, and an

AS/400 system for student and financial records management. Satellite, ITFS, and cable television technologies are being phased in for distance learning programs.

Watertown High School
825 Endeavour Dr.
Watertown, WI 53098

Kathleen E. Wagner, Principal
Phone: (414) 262-7500
Myragene Pettit, Library Media Director
Phone: (414) 262-7500
Doug Keiser, Director of Curriculum and Instruction
Phone: (414) 262-1460

Features: This Ameritech Super Schools fiber optics site features a state-of-the-art math and science technology center. A telecommunications network links students with scientists and other experts throughout the world.

Waukesha School District
222 Maple Ave.
Waukesha, WI 53186

David Campschroer, District Administrator
Phone: (414) 521-8864
Mark Blackman, Library Media Director
Phone: (414) 521-8864
Kristine Diener, Computer/Technology Coordinator
Phone: (414) 521-8864

Features: West High School and Summit View Elementary School exhibit many of the following features: a local area network for distribution of voice, data, and video; classrooms outfitted to accommodate a wide variety of new technologies; two-way television capability from classrooms; a video production studio with capability to transmit to the local CATV company; and a satellite dish to receive television programming.

West Salem School District
450 Mark St.
West Salem, WI 54669

Eugene Ertz, Superintendent
Phone: (608) 786-0700
Carol Brown, Library Media Director
Phone: (608) 786-1220

Features: The long-range technology plan developed collaboratively by the district technology committee and school board enables the online library media center catalog and CD-ROM reference materials to be available in every classroom. A wide area network uses fiber optic cabling to connect three building networks, providing each classroom with Internet access. Projects such as "Electronic Penpals" are integrated into the K-12 curriculum. Multimedia skills are taught formally in interdisciplinary classes at the middle school and high school. A satellite dish provides television programming, and several high school courses are offered cooperatively for dual credit with the area technical college.

General Bibliography

Anderson, M. Elaine. *A Guide to Curriculum Planning in Computer Education*. Madison, WI: Dept. of Public Instruction, 1987.

Based on the premise that computer literacy competencies are essential for all learners, this 120-page book provides a model for using computers and electronic media in teaching and learning and a process for efficient planning. Available as publication #7470 for $18.00 plus $5.00 s&h from the Wisconsin Department of Public Instruction, Drawer 179, Milwaukee, WI 53293-0179. Phone orders: 1 (800) 243-8782.

Barron, Ann E., and Gary W. Orwig. *New Technologies for Education: A Beginner's Guide*. Englewood, CO: Libraries Unlimited, 1993.

"Designed for teachers, library media specialists, and administrators, this guide offers an objective overview of the full range of newer educational technologies" (from back cover). Available for $27.50 prepaid from Libraries Unlimited, Dept. 9405, P.O. Box 6633, Englewood, CO 80155-6633. To order by phone: 1 (800) 237-6124.

Best, Anita, and Judi Mathis, eds. *The 1994-95 Educational Software Preview Guide*. Eugene, OR: The International Society for Technology in Education, 1995.

"Designed to assist in locating software for preview, the Guide lists 500+ titles of favorably reviewed software for K-12 classroom use. Developed by the Educational Software Evaluation Consortium, which represents computer education organizations in North America" (from the Guide). Available for $14.95 plus $4.50 s&h from ISTE, 480 Charnelton St., Eugene, OR 97401-2626. Phone: 1 (800) 336-5191; fax: (503) 302-3778.

Boss, Richard W. "Facilities Planning for Technology." *Library Technology Reports* 31.4 (July-Aug. 1995).

Explanation of cabling and computer networks (especially those used for library automation), with an analysis of methods for automated storage and retrieval systems and for condensed storage of traditional materials. This approximately 100-page single issue is available for $50.00 from ALA Editions Order Dept., 50 E. Huron St., Chicago, IL 60611. To order by phone: 1 (800) 545-2433.

Brody, Philip J. *Technology Planning and Management Handbook; a Guide for School District Educational Technology Leaders*. Englewood Cliffs, NJ: Educational Technology Pubs., 1995.

Overall planning for educational technology, including budgeting, equipment maintenance, staff development, support services, and school-based issues. Available for $34.95 from Educational Technology Publications, 700 Palisade Ave., Englewood Cliffs, NJ 07632.

Felix, Kathleen M., ed. *Only the Best: The Annual Guide to the Highest-Rated Educational Software/Multimedia, 1994/95*. Alexandria VA: Association for Supervision and Curriculum Development, 1995.

Available from the Association for Supervision and Curriculum Development, 1250 N. Pitt St., Alexandria, VA 22314-1403. To order by phone: (703) 549-9110.

Gayeski, Diane M. *Designing Communication and Learning Environments*. Englewood Cliffs, NJ: Educational Technology Pubs., Inc., 1995.

Developed from course presentations offered by the Ithaca College graduate program in corporate communication. Covers conceptual foundations, design elements, and selection of media support technologies; includes case studies. Available for $34.95 from Educational Technology Publications, 700 Palisade Ave., Englewood Cliffs, NJ 07632.

Hanson, Gordon P. *Instructional Telecommunications: A Resource and Planning Guide*. Madison: Wisconsin Dept. of Public Instruction, 1995.

This 140-page book explains how the traditional and emerging communications media, including satellites, microwave television, and fiber optic transmission systems, operate and analyzes the impact on K-12 education. Available as publication #5171 for $18.00 plus $5.00 s&h from the Wisconsin Department of Public Instruction, Drawer 179, Milwaukee, WI 53293-0179. Phone orders: 1 (800) 243-8782.

Jones, Beau Fly, Gilbert Valdez, et al. *Plugging In: Choosing and Using Educational Technology.* Washington, DC: Council for Educational Development and Research, 1995.

Based on work conducted at the North Central Regional Educational Laboratory (NCREL), the 50-page book discusses how technologies assist learning and provides charts to help school decision makers analyze needs and set goals for using technology. Available for $5.00 postpaid from the Council for Educational Development and Research, 2000 L St., Suite 601, Washington, DC 20036. For fax orders: (202) 785-3849. For bulk discounts call (202) 223-1593.

_______. *Designing Learning and Technology for Educational Reform.* Oak Brook, IL: North Central Regional Educational Laboratory (NCREL), 1994.

This 120-page book presents a framework developed to display how different levels of technology increase or decrease the engagement of students in the learning process. It makes broad policy recommendations about what needs to be in place to promote engaged learning, such as equitable student access, familiarity with workplace technologies, staff development, etc. Available for $9.95 from the North Central Regional Educational Laboratory (NCREL), 1900 Spring Rd., Suite 300, Oak Brook, IL 60521-1480. Phone: (708) 571-4700; fax: (708) 571-4716.

Kee, Eddie. *Networking Illustrated: The Full Color Guide to How it all Works.* Indianapolis: QUE (Division of Prentice Hall Computer Pub.), 1994.

Available for $24.99 from QUE, 201 W. 103rd St., Indianapolis, IN 46290.

Klasing, Jane P. *Designing and Renovating School Library Media Centers.* Chicago: American Library Assn., 1991.

Emphasizes developing educational specifications that clarify the uses of the library media program spaces. By means of descriptive case studies, this work guides the reader from needs assessment to review of the architect's plans. 114 pages, $22.00 plus $6.00 s&h from the ALA Editions Order Dept., 50 E. Huron St., Chicago, IL 60611. To order by phone: 1 (800) 545-2433.

Massachusetts Software Council, Inc. *The Switched-on Classroom; a Technology Planning Guide for Public Schools in Massachusetts.* Boston: Massachusetts Software Council, Inc., 1994.

This guide describes a participatory process for integrating technology into the classroom, documents successful examples of implementation, and provides a directory of resources (mostly in Massachusetts) to support the technology adoption process. Available for $20.00 postpaid from The Switched-on Classroom Massachusetts Software Council, One Exeter Plaza, Suite 200, Boston, MA 02116-2831.

North Carolina Department of Public Instruction. *A Primer for Cabling Design and Implementation: Considerations for Decision Makers.* Raleigh: the Department, 1992.

Technical standards and recommendations written for school personnel who will work with architects and builders in design and implementation of cabling systems. While based on North Carolina administrative rules, the technical information is useful to all network planners. For ordering and update information, write Margaret Bingham, Instructional Technology Planning and Integration, North Carolina Department of Public Instruction, 301 N. Wilmington St., Raleigh, NC 27601-2825; or call (919) 715-1512.

PC Magazine 14.6, 28 Mar. 1995.

This issue features a cover story and follow-up articles on upgrading existing computer hardware with sound, video, and related multimedia enhancements.

Ramirez, Rafael, and Rosemary Bell. *Byting Back: Policies to Support the Use of Technology in Education.* Oak Brook, IL: North Central Regional Educational Laboratory, 1994.

Provides rationale for connecting schools to resources electronically, analyzes the implications of doing this, looks at federal- and state-level funding and policies affecting technology, and makes suggestions for forming partnerships. Available for $9.95 from the North Central Regional Educational Laboratory (NCREL), 1900 Spring Rd., Suite 300, Oak Brook, IL 60521-1480. Phone: (708) 571-4700; fax (708) 571-4716.

Wisconsin Association of School Boards. *Wisconsin Schools and Technology.* Madison WI: the Assn., September 1995.

A review of the uses of information technology in 167 of Wisconsin's 426 school districts, compiled by Bill Cosh from newspaper articles and similar sources, arranged alphabetically by school district. Available from the Wisconsin Association of School Boards, Suite 500, 122 W. Washington Ave., Madison, WI 53703. Phone: (608) 257-2622; fax: (608) 257-8386.